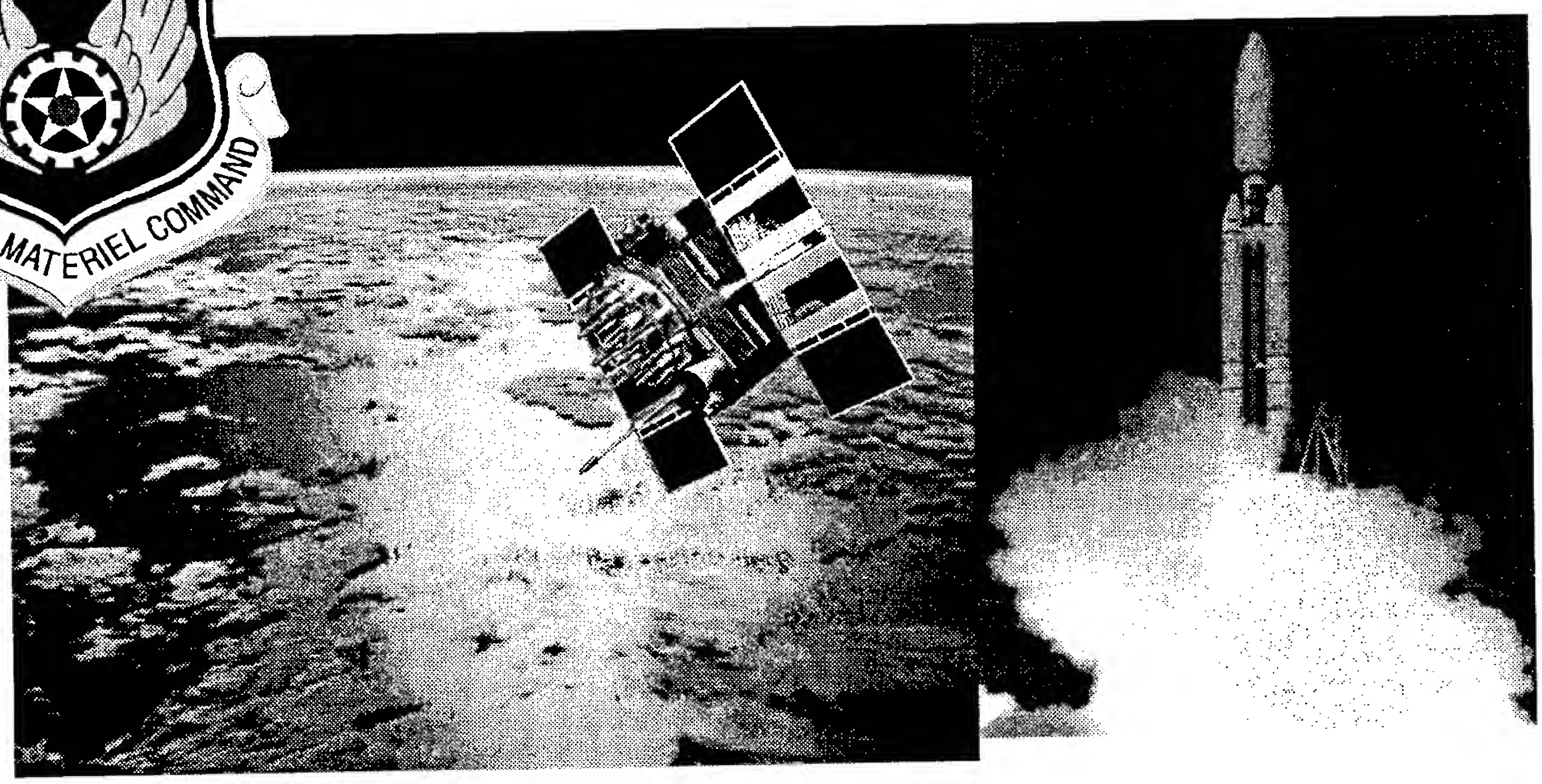
FY96

SPACE AND MISSILES TECHNOLOGY AREA PLAN



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14. Abstract

The FY 96 Space and Missiles Technology Area Plan describes Phillips Laboratory's exploratory and advanced technology development for missile propulsion technology, space systems propulsion technology, space vehicle structures and controls, advanced technology integration and demonstration, space power and thermal mangement, space sensors and satellite communications, space vehicle electronics and software, and space vehicle and missile dynamics technology. Specifically, each thrust is discussed in terms of its goals, major accomplishments, and changes from last year.

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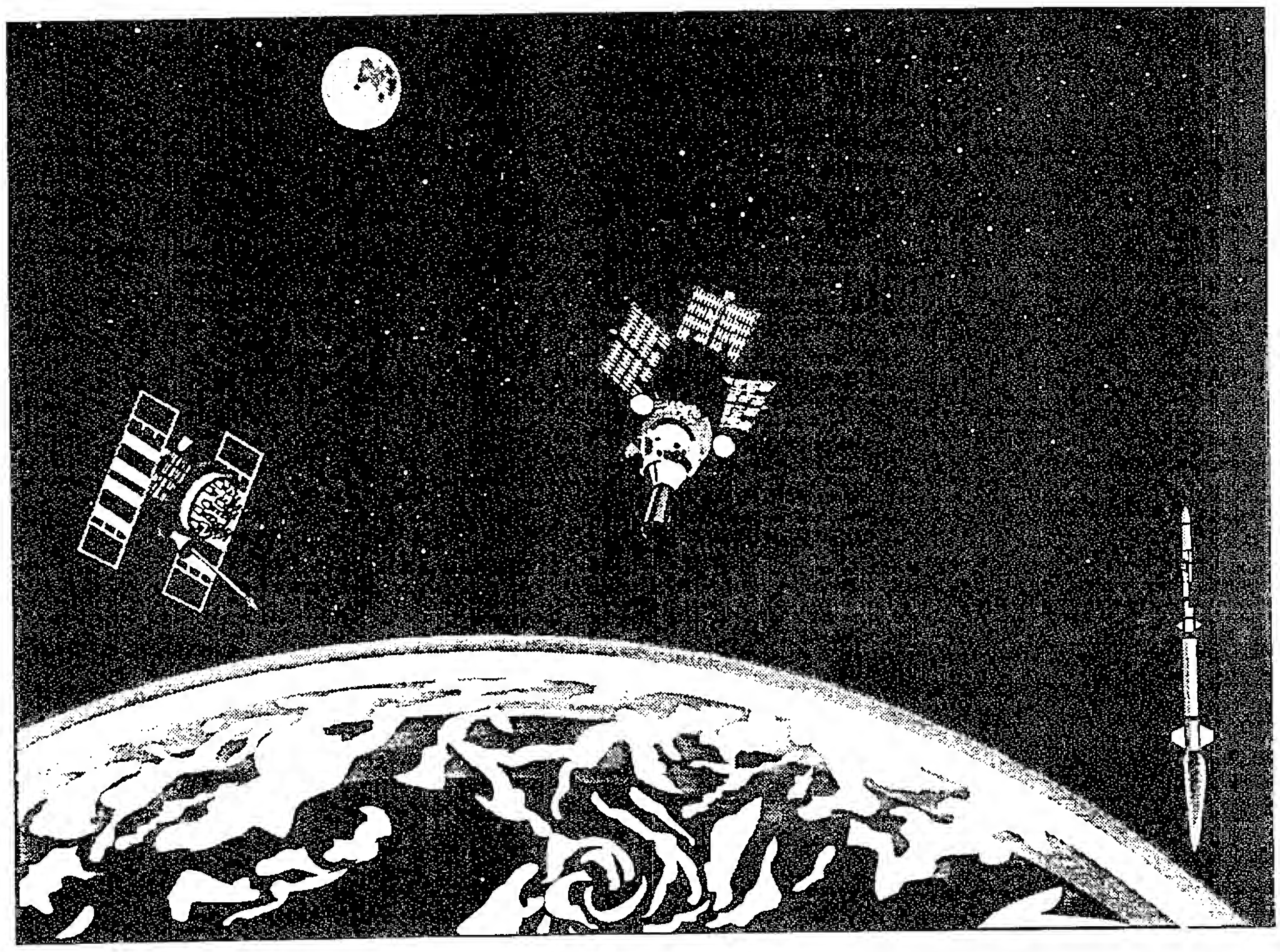
Unclassified	Unclassified	Unclassified	Unlimited	28	Lt. Kevin Byrne COM (505) 853-3191 DSN 263-3191

SPACE AND MISSILES



VISIONS AND OPPORTUNITIES

Rapid and cost effective development and transition of superior technologies for space and missile systems enable the affordable and decisive military capability of our US forces. This vision for the Space and Missiles Technology area is in concert with the Department of Defense Science and Technology (S&T) Strategy. The principle characteristic of US military strategy is technological superiority. We remain committed to developing the technologies that provide options for the warfighter, especially those capabilities that take advantage of space as an operating environment. However, we are responsive to the new reality that technological superiority alone is no longer sufficient. Our investments must include consideration of affordability.

The specific technologies pursued in the Space and Missiles Technology area are driven by military needs as enunciated by the warfighter and embodied in the five Future Joint Warfighting Capabilities:

1. To maintain near perfect knowledge of the enemy and communicate that to all forces in near-real time.
2. To engage regional forces promptly in decisive combat, on a global basis.
3. To employ a range of capabilities more suitable to actions at the lower end of the full range of military operations which allow achievement of military objectives with minimum casualties and collateral damage.
4. To control the use of space.
5. To counter the threat of weapons of mass destruction and future ballistic cruise missiles to the CONUS and deployed forces.

We respond to these needs through the Air Force Space Command mission area plans, which describe these needs in terms of deficiencies and operational concepts to overcome the deficiencies. We focus technologies in the Space and Missiles Technology area to enable operational concepts either through technology development or rapid exploitation and transition of technological opportunities.

Ultimately, the Space and Missiles Technology area seeks to develop and transition the technologies necessary to provide capabilities to take advantage of the

opportunities and overcome the challenges posed by the Future Joint Warfighting Capabilities: First, collecting, managing, disseminating, and exploiting information, including defending our information systems and disabling an adversary's. Second, evolutionary upgrading all military systems across the spectrum of conflict, indicating a need to stay abreast of a broad spectrum of technologies. Third, solving pervasive challenges with potential significant impact to the nature of war, including information access, mobility, and precision strike. Finally, protecting and enhancing the effectiveness of individuals and small units through non- and counter-proliferation. Space as an operating environment offers significant and sometimes unique characteristics for addressing these challenges and opportunities. The technologies captured in the Space and Missiles Technology area seek to enable systems and improve capabilities to take advantage of those characteristics.

The Future Joint Warfighting Capabilities define the future technology needs. However, limited budgets place constraints on our S&T program and we must prioritize. Technological superiority is a primary driver of our investment decisions in our Space and Missiles Technology area. Our investment strategy is placing more priority on improving productivity and reducing costs, and utilizing economies of scale and technology innovation of the commercial industry. Emphasis on direct commercial exploitation, assessment of commercial off-the-shelf technology for military application, and cooperative research and development is a significant part of our vision for future technology development and transition. Technology ensures that the Air Force can buy more for less. Technology that increases the effectiveness of systems means that we can accomplish more with less material. The need for affordability is a pervasive requirement that is being emphasized throughout all aspects of our Space and Missiles technology development.

The cumulative effect of the investments and efforts in the Space and Missiles Technology area on warfighter capabilities 10 and 20 years from now will be dramatic. Sensor detector, electronic, payload thermal management, payload stabilization, power generation, storage and management, and data processing and communication advances will provide the tools to develop future systems. We can make the warfighter omniscient regarding his adversaries and the battlefield, and able to communicate the information anywhere, anytime. Such awareness and ability to communicate will contribute to provide the forewarning necessary to enable engaging regional forces promptly in decisive combat. The tactical deployment of high-performance communication and sensing assets by warfighters in the field, allowing near real-time collection and communication of the information to individuals and small groups, will be made possible.

To make deploying these capabilities in the space environment affordable, investments in component weight reduction, payload performance enhancement, on-board processing capability, and lift systems will combine to make space systems remarkably smaller and lighter, and lift systems significantly more capable and less costly. Similarly, investments in operation and control technologies will result in improvements in design, integration and operation processes and corresponding reductions in cost. While the sensors themselves may or may not be developed in this technology area, the improvements in affordability will make the deployment of sensors for detecting and identifying proliferation activities realizable from a cost perspective.

Well beyond 10 years from now, the nation's ballistic missile arsenal will still reside in the same silos they occupy today, thanks to continual component improvements made possible by investments in ballistic missile technology. Those same investments provide the nation a precision, global strike capability with minimum casualties and collateral damage thereby providing one more response option for the warfighter.

Ultimately, we return to where we started. The investments made in the Space and Missiles Technology area when combined with investments and advancements made in related technology areas will enable advancements in our technology base. The resultant capabilities will make war faster and less deadly than war as we know it today.

This plan has been reviewed by all Air Force laboratory commanders/directors and reflects integrated Air Force technology planning. I request Air Force Acquisition Executive approval of the plan.

RICHARD R. PAUL
Brigadier General, USAF
Technology Executive Officer

RICHARD W. DAVIS, Colonel, USAF
Commander
Phillips Laboratory

CONTENTS

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INTRODUCTION

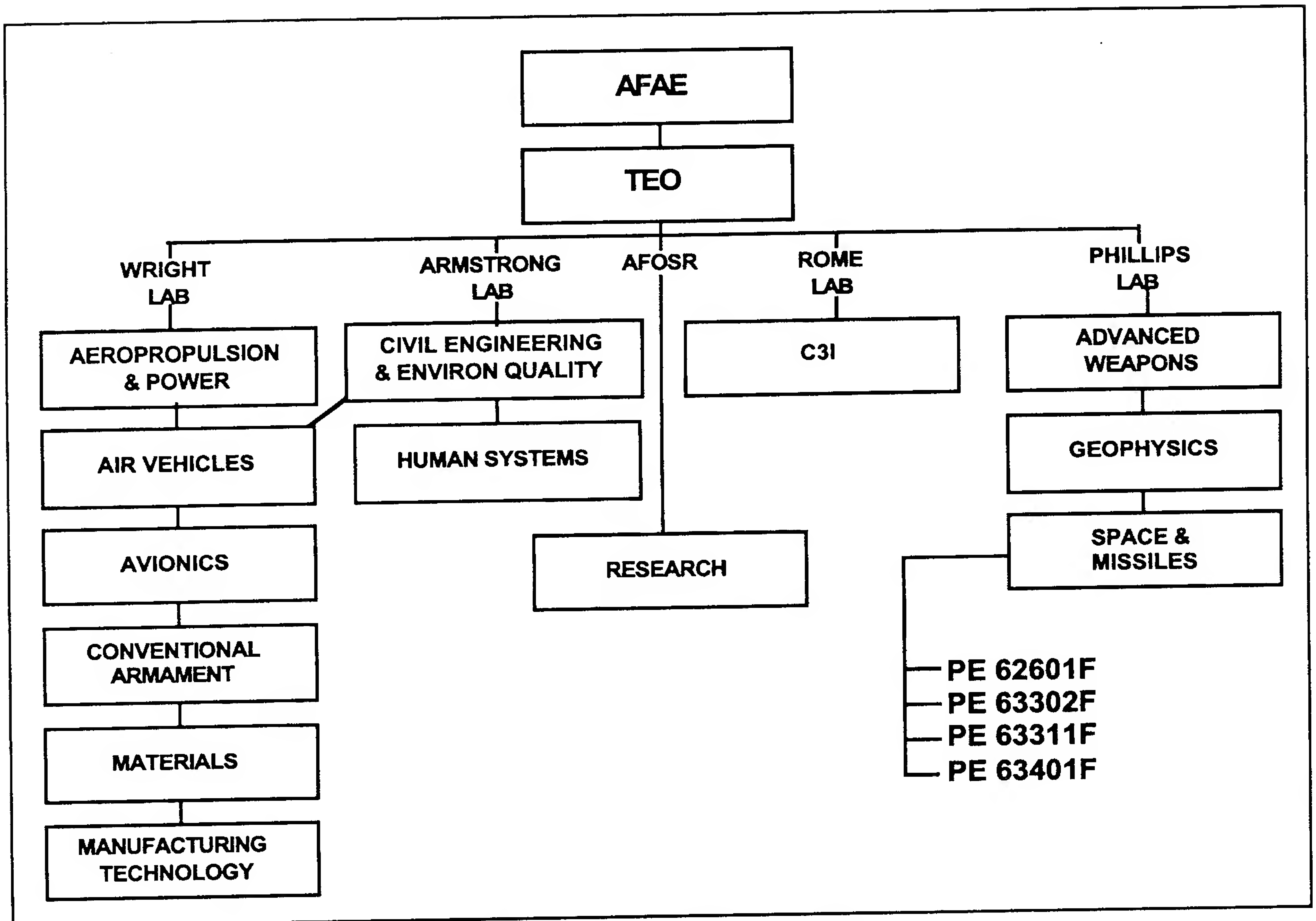


Figure 1: Air Force S&T Program

BACKGROUND

The Space and Missiles Technology Area is that part of the Air Force Science and Technology (S&T) Program charged with developing evolutionary and revolutionary technology for spacecraft and missile systems. The validated MAJCOM requirements are in Mission Need Statements, Operational Requirements Documents, and Mission Area Plan (MAP) Deficiencies. Product Divisions generate technology requirements to support advanced systems.

These near and far term requirements of the space and missile community are inserted into various Technical Planning Integrated Product Teams (TPIPT) which develop integrated requirements, system, and Space and Missile Science Technology roadmaps.

We coordinate and align the programming reflected in this Technology Area Plan (TAP) with the TPIPTs to address user requirements and provide visionary opportunities for technology push. Both enable substantial payoffs for AF systems.

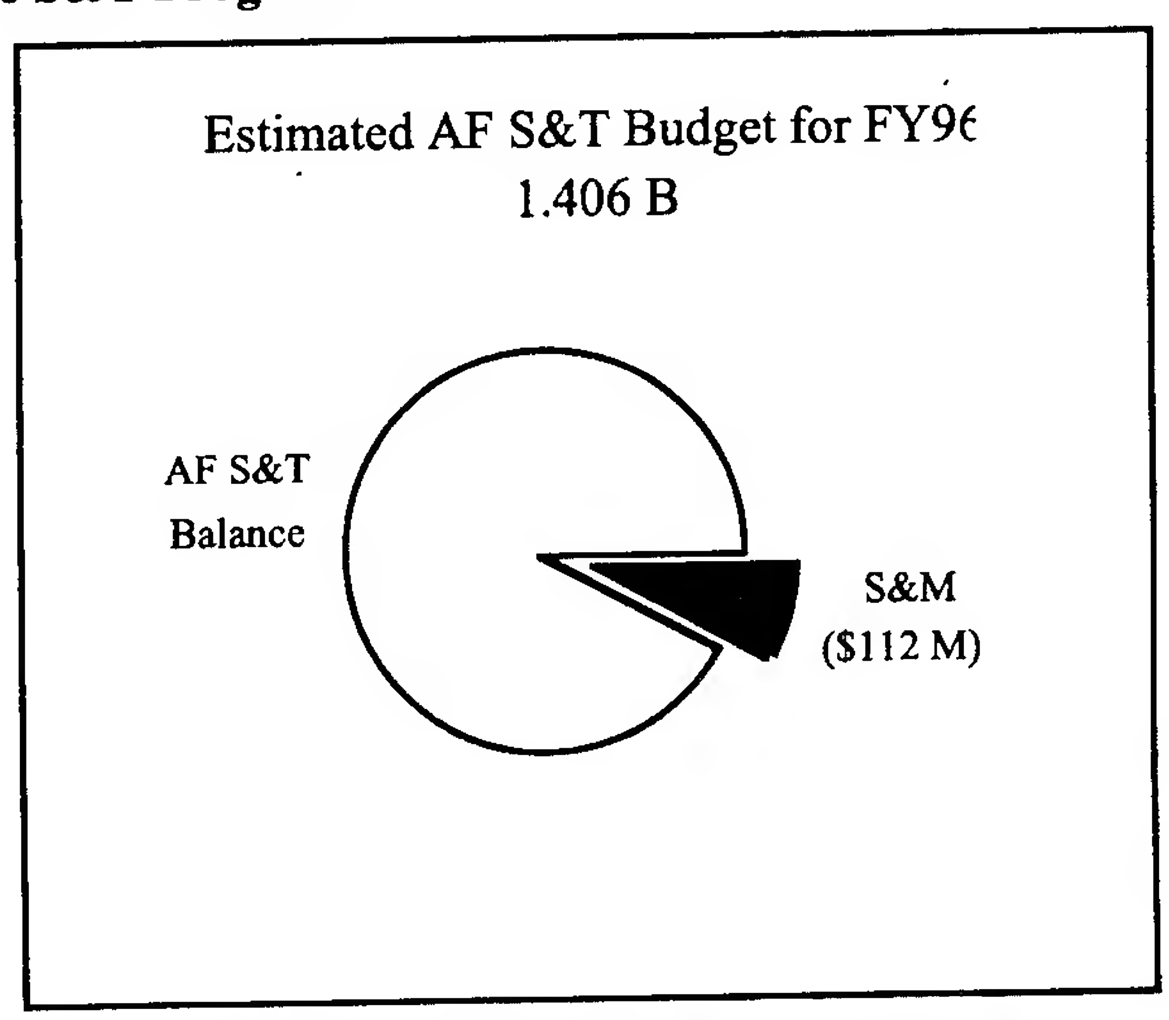


Figure 2: S&M S&T $ vs AF S&T $

We describe the programmatic implementation of our lab vision in this document to include needs, goals, major accomplishments, and changes from last year.

The Phillips Laboratory (PL) conducts a wide range of in-house and contractual programs. Total PL

S&T funding for FY96 to perform basic research, exploratory development, and advanced technology development for the Space and Missiles Technology Area approaches $112 million (ref. Fig 2).

Along with AF S&T, PL conducts programs funded by other sources. Ballistic Missile Defense Organization (BMDO) is the major source of funding.

Also, Advanced Research Projects Agency (ARPA) and NASA provide significant funding to PL for Space and Missile S&T.

We manage the technology efforts in the Space and Missiles TAP along the following eight technology thrusts to meet AF and DoD needs:

1. **Missile Propulsion Technology**
2. **Space Systems Propulsion Technology**
3. **Space Vehicle Structures and Control**
4. **Advanced Space Technology Integration and Demonstration**
5. **Space Power and Thermal Management**
6. **Space Sensors and Satellite Communications**
7. **Space Vehicle Electronics and Software**
8. **Space Vehicle and Missile Dynamics Technology**

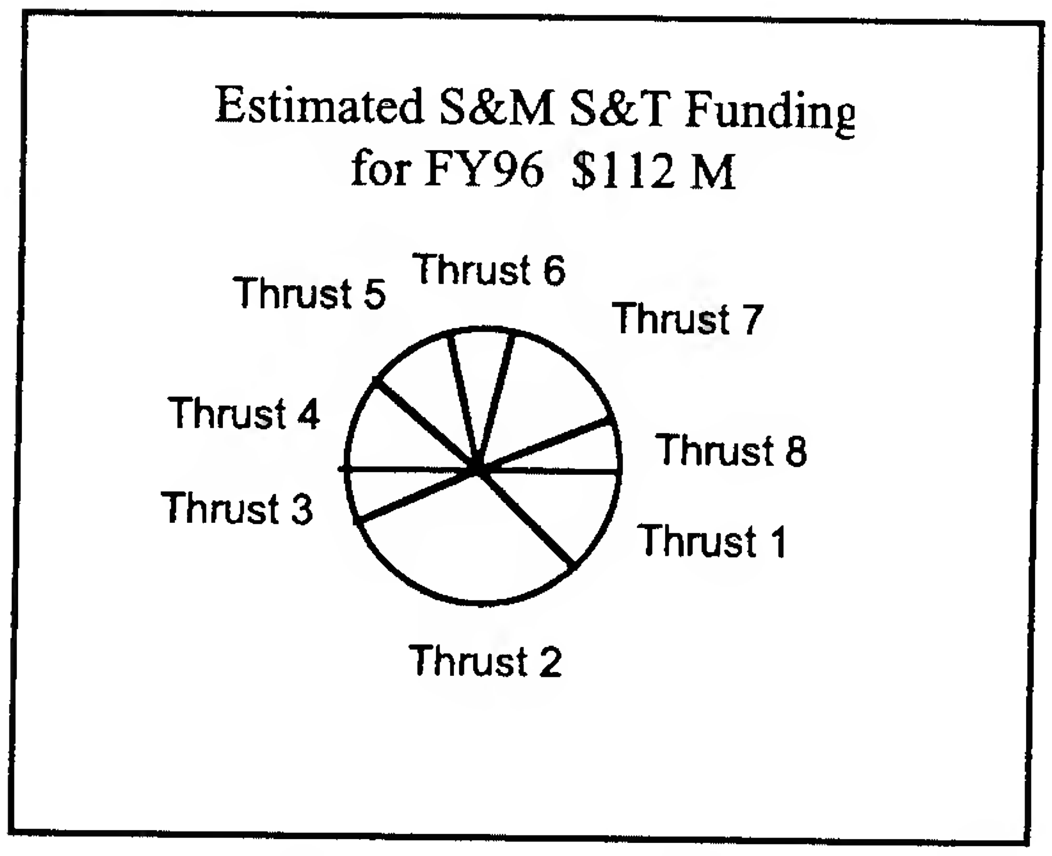


Figure 3: Thrust Funding Split

The following are recent accomplishments in Space and Missile Technologies:

Carbon densification processes developed by PL researchers reduced nozzle manufacturing time from three months down to two days dramatically reducing manufacturing time and cost. Solid rocket motor testing of these new materials showed minimal erosion which improves reliability and performance over current materials.

Our solar orbit transfer/maneuvering programs successfully fabricated a foam inflatable rigidified solar reflector for the first time ever. These reflectors fold up into small packages for launch into orbit, and then need to be deployed in space. The foam inflation process successfully demonstrated this capability. Our solar thermal thrusters also demonstrated the highest performance capabilities of any solar absorber.

The High Energy Density Material (HEDM) programs achieved the world's first isolation of nitrogen atoms in solid hydrogen, proving that high energy, diatomic atoms can be separated, stored and stabilized for extended periods of time. Eventually, higher energy atoms will be able to be tested as potential fuels. If successful, the energy created by this process could increase fuel capability by 400% over current fuels.

The joint BMDO, USAF Phillips Lab, NASA, and UK Defense Research Agency (DRA) STRV-1b satellite launched on 16 Jun 94 and successfully performed the first on-orbit adaptive structures experiment. Active piezoceramic control was used to suppress cryocooler disturbances to a simulated sensor focal plane array. The original goal was to reduce cold finger tip displacement by a factor of 10, and on-orbit experiment results have demonstrated a factor of 100 reduction.

Phillips Laboratory launched the Technology for Autonomous Operational Survivability (TAOS) integrated space flight demonstration in March 94 from Vandenberg AFB. For the past 12 months, experimenters from PL have worked successfully with Mission Control teams at Onizuka AFB and Cheyenne Mountain AFB to test the autonomous navigation survivability technologies as well as space tactics and concepts in an operational environment. To date, experiments and demonstrations involving the radar sensor and global positioning system receiver have been 100% completed, experiments demonstrating the autonomous navigation system have been 90% completed, the laser sensors have completed 80% of their experimentation while the operations demonstrations are only 50% complete. Additional demonstrations involving the payloads and operational concepts are to take place this summer. Anticipated shutdown of the TAOS mission and satellite is late Jul 95.

Established joint Navy, NASA and Air Force program to conduct life testing and failure analysis on Common Pressure Vessel (CPV) NiH2 batteries. Established failure mechanisms within the existing designs, supervised a contractor redesign and recommended new testing procedures for the batteries.

Demonstrated, for the first time, proof-of-principle design models of high reliability cryogenic cooler concepts (pulse tube and turbo Brayton) in support of user requirements at 35 and 65K.

Successfully transferred exploratory development work previously funded by BMDO in long-wavelength HgCdTe detectors and Quantum Well Infrared Photodetectors (QWIPs). Initiated work to identify and reduce performance limiting defects in HgCdTe. Developed a novel grating concept which could significantly enhance the performance of QWIPs. Initiated advanced development of very large mid-wavelength focal plane arrays.

At the request of the MILSATCOM Program Office, we initiated efforts to mature technologies for MILSATCOM payloads and satellite buses. These efforts will drastically reduce the weight of future space communication systems, allowing launches on medium launch vehicles and saving tens of millions' dollars. Coordinated all of these efforts with ongoing 6.2 and 6.3 communication system development work at Rome Laboratory.

A Memorandum of Understanding was drafted with a consortium of SMC SPOs. The consortium will provide additional FY95 and 96 funding to complete the development of two 32-bit processor programs historically funded by PE63401F.

Successful flight of the Missile Technology Demonstration. This flight showed on board real time navigation solutions for range instrumentation and safety.

Developed a PC based orbit determination and identified deficiencies in AFSPC orbit software for processing highly elliptical orbits.

RELATIONSHIP TO OTHER TECHNOLOGY PROGRAMS

The Space and Missiles Technology Area is broadly based and supports many AF mission areas. These complementary relationships allow for maximum leverage of the R&D investment.

The Air Force Office of Scientific Research (AFOSR) supports numerous PL basic research efforts. AFOSR chemical science supported energetic materials research flows directly to the Applied Research In Energy Storage (ARIES) program efforts investigating HEDM. Aerospace science research feeds investigations of combustion mechanisms, plume phenomena, and plasma diagnostics. It supports research into basic understanding of composite materials bonding and fracture mechanics. Spacecraft initiatives benefit from basic research in spacecraft dynamics and control phenomena as well as Project Forecast II-derived research on HEDM synthesis.

Wright Laboratory (WL) provides manufacturing and materials technology development for several thrusts. Manufacturing Technology (MANTECH) provides the methodology for scaling research materials into production quantities. The Materials Technology Area assists in addressing challenges associated with lightweight components. Selected propulsion technology components have been carried from exploratory through advanced development and become candidates for MANTECH demonstrations. We initiated similar efforts for major spacecraft components. PL uses materials developed by WL and applies them to space and rocket propulsion vehicles. PL and WL also benefit from their complementary nondestructive evaluation programs. Additional cooperative efforts exist with the thrust axis accelerometer, precision fiber optic gyroscope and micro-inertial instruments programs. PL is providing 6.2 funding for the gyroscope in FY95 and 96 and has agreed to add 6.3 funding to all three programs starting in FY97.

Rome Laboratory (RL) and WL provide 6.1 and 6.2 technology programs in the area of antennas, component reliability, software, photonics, communications, and signal processing. We apply these to PL 6.3 technology efforts. We will continue to coordinate with RL through the Inter Laboratory Investment Plan (ILIP) to meet AF Space and Missile technology needs.

PL, as the Space and Missile Power Laboratory for the Air Force, develops batteries for primary and secondary systems. PL collaborates with WL in the area of some battery development and test (Sodium Sulfur (NaS) and thermal batteries) to serve our user and avoid duplication.

The space environment (plasma, radiation, thermal gradients) negatively effects solar cells, batteries and power system electronics. Through joint flight experiments (like PASP+) with the Geophysics Directorate, we incorporate understanding of these effects in our power system development.

We actively coordinate ultraviolet sensor and component characterization activities and environmental modeling with the Geophysics TAP. Our work supports the Advanced Weapons TAP by assissting in development of Infrared sensors for the Maui and STARFIRE Optical Range. We work antenna and EHF component development efforts collaboratively within the C^3I TAP. We joined with the MILSATCOM Program Office to develop technologies for Advanced MILSATCOM payloads for FY95 and beyond.

BMDO provides considerable resources focused on kinetic energy weapons and plume phenomenology. We are developing small, modular satellites, Advanced Liquid Axial Stage, and Advanced Solid Axial Stage propulsion systems for BMDO missions. BMDO has been supporting adaptive structure technology development and precision pointing experiments.

The Advanced Research Projects Agency (ARPA) sponsors downlink EHF antenna technology and GPS Guidance Package efforts.

PL is working with NASA Goddard Space Flight Center to develop high-density memory modules for two satellite programs. We will produce space-qualified single-layer modules and multi-layer modules next year. Joint data collection efforts using NASA/JPL SIR-C/X-SAR and TOPSAT are critical to the active sensor work in the AF.

PL is a member of the Space Technology Interagency Group (STIG) Information Processing Committee, coordinating programs with Rome Laboratory, NASA, Wright Laboratory and the other Services in Communications, Sensors, and Processing and Electronics. A LASERCOM working group has been established with US government agencies.

This year the NAVY has lead responsibility for the Joint Service Program Plan (JSPP) for Space Vehicles Technology. The objective of the JSPP is to make positive, substantive contributions to the Project Reliance effort initiated by the Tri-Service Joint Directors of Laboratories (JDL) by adapting to change and down sizing, developing joint programs, leveraging services' and DoD agencies' technical expertise, and expanding the

planning process. The Space Vehicles Technology Panel is seeking to improve coordination among service laboratories performing or funding space related science and technology programs. The intent of the JSPP is to improve science and technology development through better planning across the services, and to demonstrate improved technical performance and reduced cost by more cooperative programs.

Modeling and simulation efforts in the S&M TAP support the Army's obscurants modeling and transporter - erector - launcher live simulator development, and the Naval Postgraduate School's Unmanned Aerial Flight Simulator. Passive sensor efforts address deficiencies in the Army's USASSDC sensor packaging program.

European Space Agency (ESA) Infrared Space Observatory Spectrometer used detector technology developed by PL. We continue to develop detector material technology in conjunction with international partners. The TTCP on STP-6 is being coordinated with several international partners.

CHANGES FROM LAST YEAR

The new Space Structure Laboratory being built at Kirtland AFB will allow for the consolidation of operations from 8 buildings at Kirtland AFB and Edwards AFB into one building. The move of personnel from other locations will be completed in FY95.

A three-tiered program to provide a full-service, integrated set of complimentary demonstration capabilities has been initiated. Services range from ground-based "hardware-in-the-loop" experiments to technology flight experiments such as the MIGHTYSAT or balloon programs to integrated space flight demonstrations such as the Integrated Space Technology Flights (ISTF) program

The Space Nuclear Power Sub-thrust (5B) has been eliminated. Our only nuclear effort (TOPAZ) has been folded into the new Space Power Sub-thrust (5a).

Congressional language restricted funding for advanced space communications work in PE 63401 Project 3784 in FY94, citing duplication of effort with MILSTAR technology development efforts. Adding evaluation and characterization of commercial components/technology for military applications.

Initiated new programs to develop a space-qualifiable hardened commercial Digital Signal Processor and Field Programmable Gate Array (FPGA). Both products are essential to space systems as evidenced by more than 30 letters of endorsement we have received from potential users.

Frontier Arena is a new initiative to support AF customers and the warfighter with M&S needs.

Congressional language required Advanced Guidance and Reentry Vehicles be extensively modified. Advanced Guidance funds were reduced by more than $15M. This amount of money allowed us to complete the Critical Design Review.

Responding to Congressional language, the Reentry Vehicle effort was terminated in FY95. Reentry materials are being pursued by the Materials Directorate.

THRUST 1: MISSILE PROPULSION TECHNOLOGY

USER NEEDS

The Air Force Policy of "Global Presence" cites Strategic Agility and Lethality as tenants needing "technological innovations" to "enhance U.S. ability to exert presence." The following SMC/AFSPC and ACC Development Plans also require propulsion improvements to fulfill critical deficiencies:

MISSILE OFFENSE, AIR TO SURFACE, and COUNTERAIR - Motor Service Life Prediction and Extension, High Performance Environmentally Acceptable Propellants, Low Cost Environmentally Acceptable Manufacturing Processes

GLOBAL DETERRENCE - Motor Aging and Surveillance

CONVENTIONAL DETERRENCE - Missile Propulsion Material Applications, Global Range and Survivability, Missile Propulsion Technology, Missile Propellant Non-Destructive Test Technology, Solid Rocket Motor Manufacturing, Reliability

RECONNAISSANCE/SURVEILLANCE - Cost and Survivability, Prompt Response without Force Deployment, Long Range Strike Capability

COUNTERSPACE, MISSILE WARNING - Survivability

MISSILE DEFENSE - Survivability, Propellant Development

NON-SPACE - Fast Reaction Tactical Missiles, Less Time to Target, Increased Range, Throttle on Demand, Low Cost, Increased Environmental Compliance.

GOALS

The propulsion needs identified above will be fulfilled by achieving the goals set forth in the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) initiative. IHPRPT's vision is to double solid rocket propulsion capability by 2010 through the development of advanced, innovative rocket propulsion technology.

Fulfillment of the IHPRPT near term goals will:

- increase either warhead delivery capability or range by 10% in the year 2000.

For divert (steering control) propulsion systems:

- the number of theater missile defense systems to cover an area can be reduced by 26% in 2000.

By 2010, the IHPRPT goals will:

- double tactical and strategic warhead capability or range and,
- reduce necessary theater missile defense systems for divert propulsion by 60%.

To do this, solid propellant and motor component development is crucial. The Phillips Lab (PL) rocket propulsion directorate has the only programs which develop solid rocket propulsion technology for all Air Force strategic and tactical missile systems.

Our tactical propulsion efforts initiated in FY94 have been coordinated with the NAVY under the Project RELIANCE agreement. We are working together to satisfy the range, survivability, and rapid response deficiencies stated above by:

- developing low signature high performance propellants.

Strategic programs focus on:

- developing environmentally acceptable solid rocket motors while extending the life, range, and reliability of our current solid strategic propulsion systems.

Our solid propellant technology and component development technology will:

- improve ballistic missile motor service life in both existing and new systems.

These programs will also:

- dramatically reduce manufacturing and support costs.

While PL is the leader in developing this solid rocket propulsion technology, many challenges remain. We must:

- develop motor manufacturing processes that eliminate harmful chemicals used in rocket motor manufacturing
- develop long life, high performance, environmentally acceptable solid propellants while maintaining properties/integrity equal to current solid propellants
- develop methods to reclaim and reuse propellant ingredients from motors no longer in service, decreasing costs and increasing safety by eliminating the need to store highly explosive materials
- develop motor components capable of withstanding the increased temperatures created by new environmental propellants.

Our polymer material programs focus on:

- developing longer life, stronger motor components.

Production costs of insulation and nozzles will decrease by as much as 40%. Large payoffs in other component processing programs like our carbon densification and lightweight coatings are:

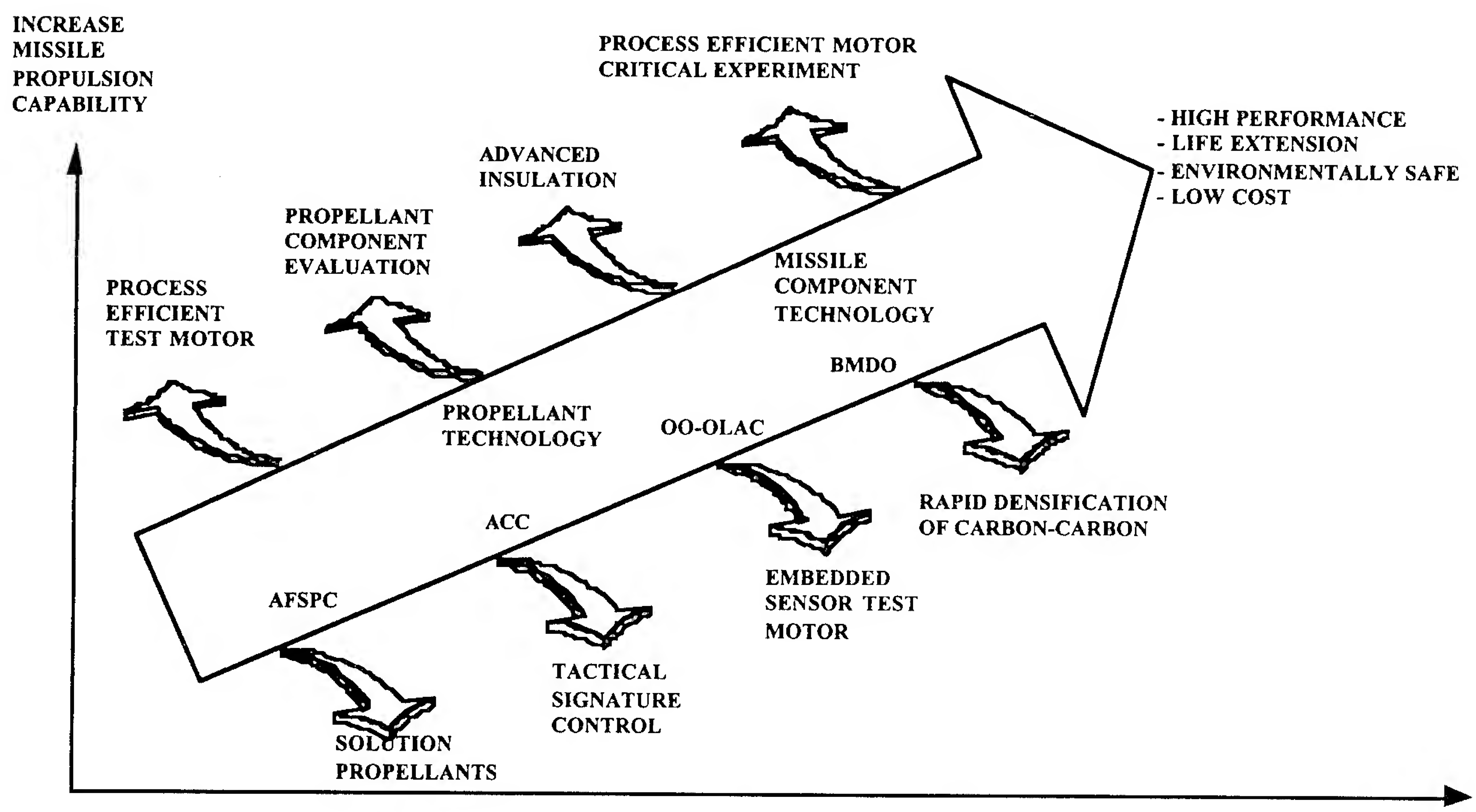
- cutting production time and costs,
- decreasing nozzle erosion rates (which increase reliability, performance, and range) and
- increasing oxidation resistance (which also increases reliability).

Our carbon composite and coatings programs also have significant dual use opportunities.

MAJOR ACCOMPLISHMENTS

Carbon densification processes developed by PL researchers reduced nozzle manufacturing time from three months down to two days dramatically reducing manufacturing time and cost. Solid rocket motor testing of these new materials showed minimal erosion which improves reliability and performance over current materials. Our first test firing of the new "process efficient" motor with a new "solution" propellant validated a simpler, lower cost, safer manufacturing

Thrust 1
Missile Propulsion Technology



process which reduced the number of steps from 23 (on conventional motors) down to 9. This manufacturing method is capable of being automated (further reducing costs), and the processing method eliminates the unsafe transport of current explosive solid rocket motors by allowing the explosives to be loaded at the launch site. Previous manufacturing methods prevented this capability. New hybrid rocket testing demonstrated capabilities that show a high potential for low cost hybrid rockets to replace current solid and liquid rocket capabilities.

CHANGES FROM LAST YEAR

In FY95, the IHPRPT initiative included strategic missiles under "Space Boost Propulsion" and divert propulsion under "Satellite Propulsion." FY96 combines the tactical, divert, and strategic missile efforts under the IHPRPT "Missile Propulsion" category. The propulsion issues for strategic and tactical missiles, excluding signature criteria, have similar critical needs. Additionally, the satellite "Control/Divert Propulsion" category has been renamed the "Spacecraft Propulsion" category.

Milestones	Year	Metrics
Develop/demo new propellant formulations	FY96	Verify high performance, environmentally safe propellant
Develop flaw assessment capability for motor aging	FY96	Provide defect effect data base for motor aging/surveillance
Determine feasibility of revolutionary motor processing technique	FY97	Demonstrate revolutionary motor processing technique on full scale motor
Adapt C/C rapid densification technique to nozzle fab	FY97	Fire high density low erosion rocket motor nozzles
Develop in-situ health monitoring system at lab scale	FY98	Demo full scale health monitoring system
Develop Structural/Ballistic Interaction (SBI) code	FY98	Predict SBI for current motors

THRUST 2: SPACE SYSTEMS PROPULSION TECHNOLOGY

USER NEEDS

The Air Force Policy of "Global Presence" cites Situational Awareness and Strategic Agility as tenants needing "technological innovations" to "enhance U.S. ability to exert presence." The following SMC Development Plans and NASA requirements also demand propulsion improvements to fulfill critical deficiencies:

SPACELIFT - High Performance, Advanced, Cryogenic and Liquid Rocket Propellants and Engines, Low Cost Solid and Hybrid Motors, Low Cost Manufacturing, High Performance Low Cost Expendable Engines, Advanced Propulsion/Power Conversion for Electric Propulsion (for Stationkeeping/Maneuvering) and Solar Thermal Propulsion (for Orbit Transfer), Advanced Orbit Transfer Concepts, Manufacturing Technologies

RECONNAISSANCE/SURVEILLANCE - Cost and Survivability, Large Payload Spacelift Systems

WEATHER - Small Satellite Technology

NAVIGATION - Modernization of Current Systems, Upgraded Future Systems to Replace Current Systems with Lower Power Consumption, Improved Power Conversion, Advanced Attitude Control, Advanced Electric Propulsion and Solar Propulsion

NASA - Advanced Reusable Spacelift, Low Cost Reliable Access to Space.

GOALS

The propulsion needs identified above will be fulfilled by achieving the goals set forth in the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) initiative. IHPRPT's vision is to double spacelift propulsion capability by 2010 through the development of advanced, innovative rocket propulsion technology.

Fulfillment of the IHPRPT near term goals for spacelift (by 2000) will:

- increase expendable payload to orbit capability by 9% or reusable payload to orbit capability by 71% (over the life of the reusable system)
- reduce payload launch costs by 19%.

Satellite propulsion systems (by 2000) will:

- extend their life in geosynchronous orbit (GEO) by 25%
- double repositioning capabilities or
- increase allowable satellite mass by 10% with present lifespan capabilities.

By 2010, the IHPRPT spacelift goals will:

- increase expendable payload to orbit capability by 22% or reusable payload to orbit capability by 206% (over the life of the reusable system)
- reduce payload launch costs by 42%.

Satellite propulsion systems (by 2010) will:

- extend their life in GEO by 45%
- increase repositioning capability by 5 times or
- increase allowable satellite mass by 30% with present lifespan capabilities.

To do this, liquid, solid and hybrid spacelift development is crucial. Chemical, electric, and solar spacecraft propulsion development is also critical to achieve the satellite improvements for stationkeeping, orbit transfer, and maneuvering. Extraordinary increases in maneuvering and stationkeeping capabilities are anticipated through the improvements in satellite electric propulsion systems. Chemical and solar thermal satellite propulsion system improvements will provide for the increases in orbit transfer performance. Anticipated decreases in satellite propulsion system weight and size will provide additional cost reductions.

Together, the spacecraft and spacelift propulsion efforts will enable the United States to have faster, more reliable access to space for lower costs.

In response to the above needs, PL develops technology for:

- high performance, low cost expendable propulsion
- advanced liquid and cryogenic reusable and expendable propulsion
- orbit transfer, maneuvering, and stationkeeping propulsion
- low cost, rapid prototype thrust cell and component manufacturing technology
- high energy materials for potential use as propellants.

Present propellant candidates being researched could:

- increase performance (specific impulse) up to 50% over the best currently available propellants.

These technologies will provide the technical solutions to develop next generation space systems in addition to upgrades for existing space vehicles. The major challenges to achieving the spacelift goals are addressed by our programs which:

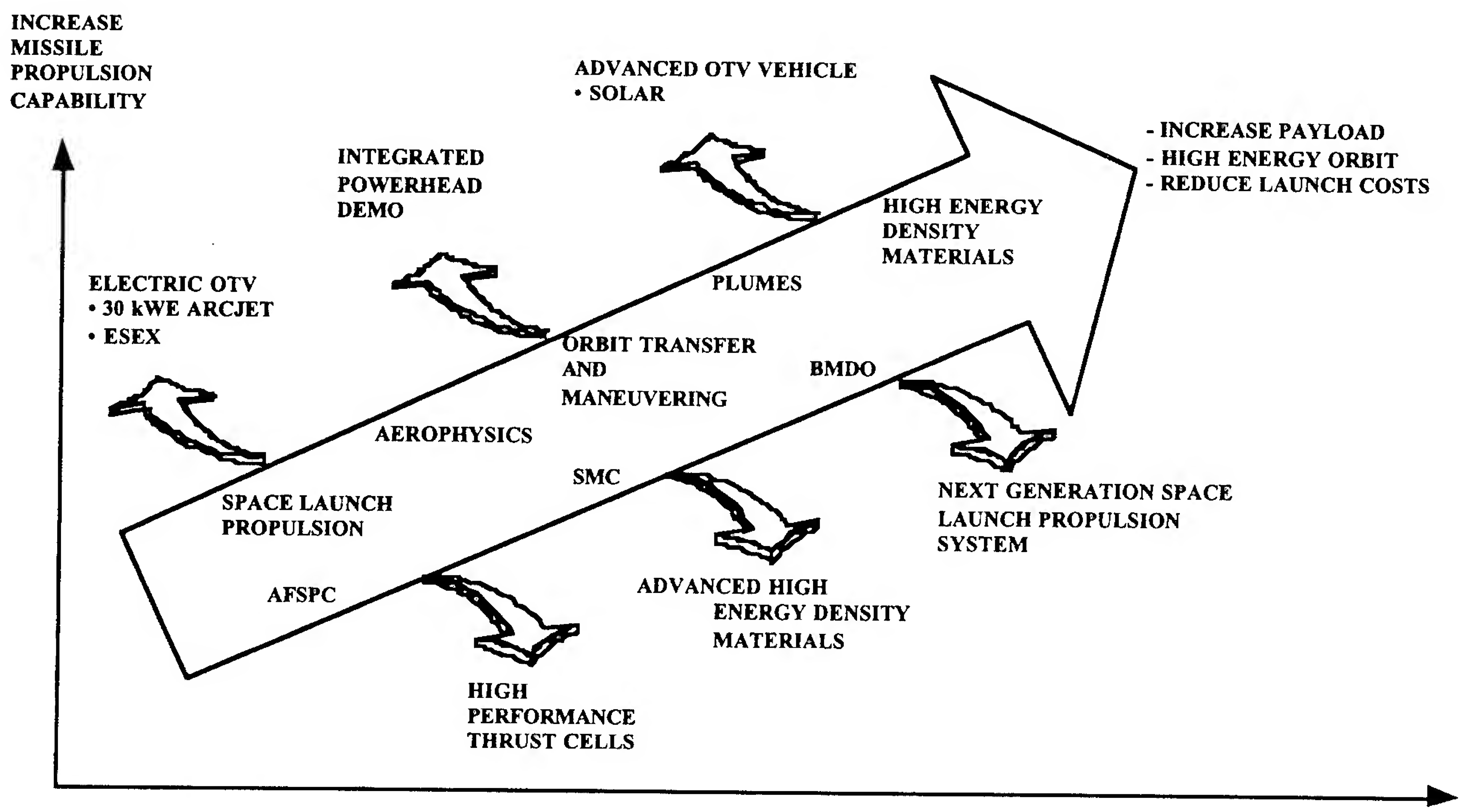
- apply advanced materials to increase the life and decrease the weight of components
- integrate health management sensors in the design of components eliminating the high cost of retrofitting these sensors
- investigate combustion technology and improve current engine designs to make stable, reliable, low cost propulsion engines for boost and orbit transfer

coordinate our efforts closely with the Navy, Army, NASA, and Industry to lower development costs for everyone involved. IHPRPT is based on our cooperative efforts with the Army, Navy, NASA, Air Force, and all U.S. propulsion companies.

MAJOR ACCOMPLISHMENTS

New high pressure injector tests were performed to validate several injector designs. Faulty injectors cause poor combustion decreasing efficiency and potentially causing launch failure. New, hydrostatic bearing technology was developed for reusable engines. These bearings have no touching metal surfaces which result

Thrust 2
Space Systems Propulsion Technology



in no wear, highly reliable engine bearings. The Integrated Powerhead program is integrating these bearings into its design and design reviews are presently underway. A high power (30 kW) ammonia arcjet propulsion system for orbit transfer was flight qualified for integration into the SMC "ARGOS" space test vehicle. This system will be launched on ARGOS in FY96 to validate high power electric propulsion orbit transfer capabilities.

Our solar orbit transfer/maneuvering programs successfully fabricated a foam inflatable rigidified solar reflector for the first time ever. These reflectors fold up into small packages for launch into orbit, and then need to be deployed in space. The foam inflation process successfully demonstrated this capability. Our solar thermal thrusters also demonstrated the highest performance capabilities of any solar absorber.

The High Energy Density Material (HEDM) programs achieved the world's first isolation of nitrogen atoms in solid hydrogen, proving that high energy, diatomic atoms can be separated, stored and stabilized for extended periods of time. Eventually, higher energy atoms will be able to be tested as potential fuels. If successful, the energy created by this process could increase fuel capability by 400% over current fuels.

CHANGES FROM LAST YEAR

In FY95, our IHPRPT initiative included strategic missiles in our space boost propulsion technology area. FY96 combines tactical and strategic missile efforts under the IHPRPT "Missile Propulsion" category and separates the boost propulsion into a separate "Spacelaunch Propulsion" category. Additionally, the satellite "Control/Divert Propulsion" category has been renamed the "Spacecraft Propulsion" category.

Milestones	Year	Metrics
ESEX flight demonstration on ARGOS Investigate HEDM propellant candidates	FY96 FY96	Data analysis of high power electric propulsion for OTV Demo stability of selected HEDM propellants
Demo hydrostatic bearing capability	FY96	Test reusable hydrostatic bearings in liquid hydrogen
Develop/Demo low cost thrust cell fabrication tech	FY97	Hot fire test low cost thrust cells
Develop/test injector design codes	FY97	Validate injector design codes
Demo integrated powerhead (IPD) preburner/turbomachinery	FY98	Test IPD engine conditions. Quantify performance, operability, and reliability improvements
Develop/test altitude compensating nozzle design	FY99	Demo altitude compensating nozzle design
Design and test solar rocket OTV	FY00	Test solar deployment in simulated zero-G altitude conditions

THRUST 3: SPACE VEHICLE STRUCTURES AND CONTROLS

USER NEEDS

Many SMC Development Plans identify several structures technologies as critical to meeting AFSPC Mission Area Plan deficiencies. These include:

SPACELIFT - Lightweight LV Structure, Composite Cryogenic Propellant Tank, Launch Vehicle Isolation System
MISSILE WARNING - Advanced Composite Bus Structure, Lightweight Solar Array, Lightweight Antenna, Multifunctional Structure
BMD/C3 - Advanced Composite Bus Structure, Lightweight Solar Array, Lightweight Antenna
SPACE SURVEILLANCE - Optical Precision Platform Experiment, ACTEX Flight Support, IH Structures and Controls
MILSATCOM - Advanced Composite Bus Structure, Multifunctional Structure, Lightweight Solar Array, Lightweight Antenna, Magnetic Suspended Reaction Wheel
NAVIGATION - Advanced Composite Bus Structure, Multifunctional Structure, Lightweight Solar array, Lightweight antenna

GOALS

The structures area has two primary technology sub-areas: Advanced Structural Components (ASC) and Structural Control & Vibration Damping (SCVD). The goals/time frame for each of these sub-areas appears below.

The baseline for our goals is the 1995 current state of the art:

ASC (Advanced Structural Components)
- For satellites, the structural subsystem averages 20% of mass and 13% of cost
- For launch vehicles, the structural subsystem averages less than 14% of the overall mass and 30% of cost

SCVD (Structural Control & Vibration Damping)
- Subsystems requiring precision pointing are hardmounted to satellites and must live with spacecraft disturbances as part of their error budget resulting in degraded performance. On a case by case basis, attempts have been made to passively isolate either the disturbance source or the payload
- For large space-based laser systems, the Phillips Lab has demonstrated 1000:1 disturbance attenuation using system level isolation between the telescope and the laser and 100:1 improvement in farfield line of sight using active structural control of the telescope
- Satellites launched on MLVs such as Delta II are subjected to pseudo-static loads $\pm$ 2.5 gs (axial) and dynamic loads of $\pm$ 3.0 gs (lateral) and $\pm$ 0.6 gs (axial) at the separation plane during launch and must be designed to survive these loads

Our near term goals for 2001 are:

ASC
- Reduce satellite structural mass by 40% and reduce cost by more than 10%
- Reduce launch vehicle structural subsystem cost by 25%

SCVD
- Decrease dynamic launch loads to which a satellite is subjected by a factor of 5
- Reduce pyrotechnic-shock to which satellites are subjected by more than two orders of magnitude
- Decrease on-orbit disturbances experienced by payloads by a factor of 10

The far term goals for 2011 are:

ASC
- Reduce satellite structural mass by 75% and reduce cost by more than 25%
- Reduce launch vehicle structural subsystem cost by a factor of 10

SCVD
- Decrease dynamic launch loads to which a satellite is subjected by a factor of 20
- Decrease on-orbit disturbances experienced by payloads by a factor of 100

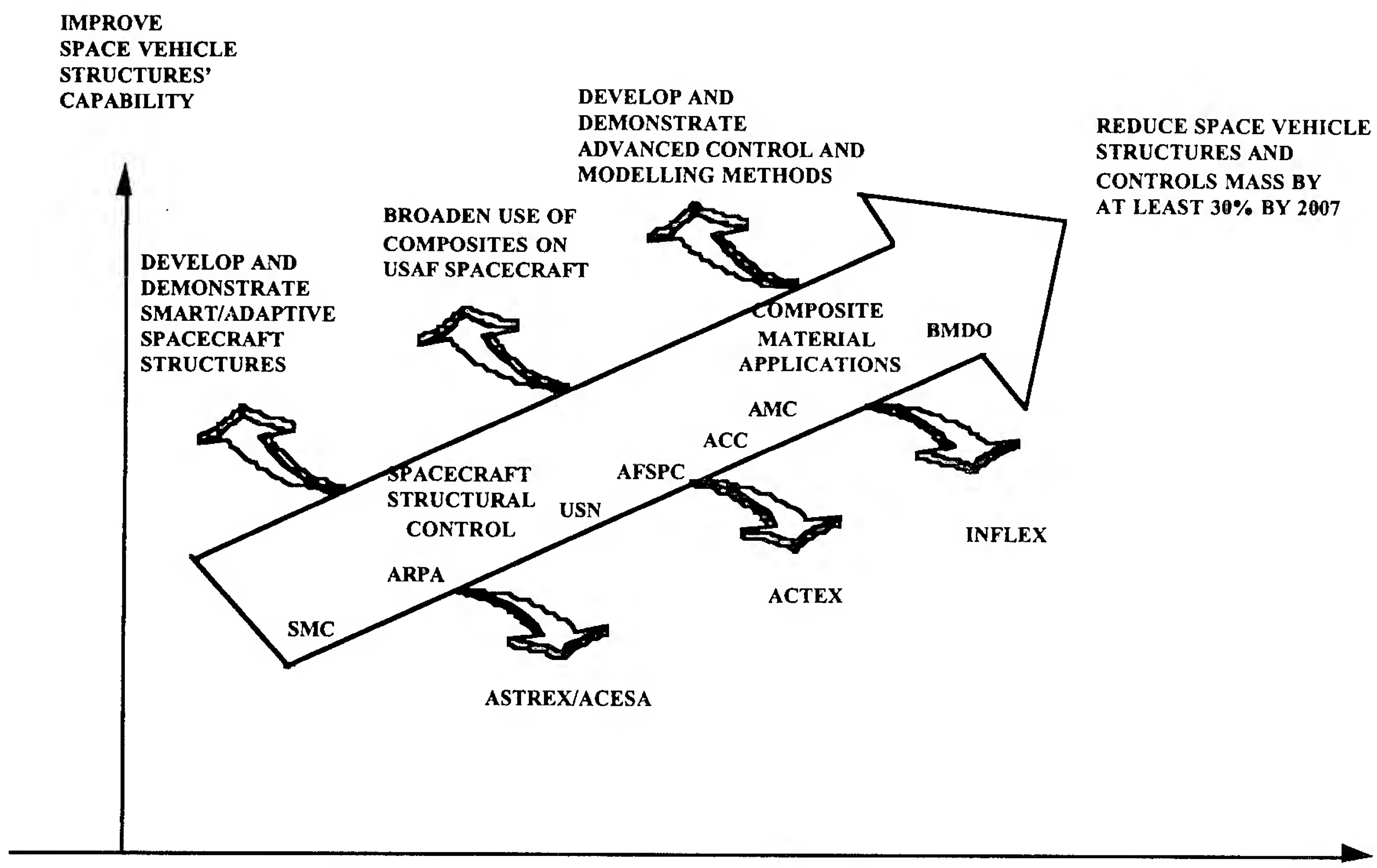
MAJOR ACCOMPLISHMENTS

The joint BMDO, USAF Phillips Lab, NASA, and UK Defense Research Agency (DRA) STRV-1b satellite launched on 16 Jun 94 and successfully performed the first on-orbit adaptive structures experiment. Active piezoceramic control was used to suppress cryocooler disturbances to a simulated sensor focal plane array. The original goal was to reduce cold finger tip displacement by a factor of 10, and on-orbit experiment results have demonstrated a factor of 100 reduction.

In a series of experiments conducted during this last year, we conclusively demonstrated that correct ground simulation of space environmental effects on structures requires simultaneous, rather than sequential, exposure to the individual space environment factors. Results of these ground experiments closely matched data obtained from past space experiments, explaining the major discrepancies between previous ground and space test data.

Martin Marietta, under contract to the Phillips Laboratory, this year built and tested the first proof of concept panel as part of their effort to demonstrate the

THRUST 3
SPACE VEHICLE STRUCTURES AND CONTROLS



feasibility of the Multi-Functional Structures concept. (Essentially, a Multi-Functional Structure is one in which the communications wiring, power lines, etc. are integrally contained in the load bearing structure.) Martin is using integrated circuit fabrication techniques to deposit pathways/circuits into the face sheet of a composite/honeycomb structure. This is an emerging technology area in which the Phillips Laboratory has the national lead. ARPA, BMDO, USAF, and Martin are jointly funding the effort, which could potentially reduce electronic enclosure and harness weight by up to 75% and increase payload mass fraction 25%. This technology has already been baselined for NASA's next generation spacecraft project, Millennium.

CHANGES FROM LAST YEAR

The new Space Structure Laboratory being built at Kirtland AFB will allow for the consolidation of operations from 8 buildings at Kirtland AFB and Edwards AFB into one building. The move of personnel from other locations will be completed in FY95.

Also new in FY 95 was the addition of two new sources of funding. ARPA provided funding for multi-functional structures while OSD Nunn added funding for the Optical Precision Platform Experiment and the composite module, both to be flown on STRV-2 satellite.

MILESTONES	YEAR	METRICS
Flight Test of Shape Memory Alloy Release Device	FY97	Successful Demonstration of Performance Requirements
Prototype Fabrication and Testing of Smart Mechanisms	FY97	Demonstrate 30% reduction in cost, 50% savings in power, and 40% decrease in weight
Optical Precision Platform Experiment Flight Test	FY99	Demonstrate on-orbit 100 times isolation of satellite disturbances

THRUST 4: ADVANCED SPACE TECHNOLOGY INTEGRATION AND DEMONSTRATION

USER NEEDS

Air Force Space Command (AFSPC) has a critical need to develop standardized, affordable, and more efficient space system designs and operational practices to meet the needs of the warfighter beyond year 2000. Methods are in place to identify AFSPC needs and deficiencies through the use of AFSPC's Mission Area Plans (MAPs) and Space and Missile Systems Center (SMC) Technology Planning Integrated Product Teams (TPIPTs). The critical step in providing the required emerging technologies which address the needs and deficiencies identified in this process is orderly and routine space, near-space, and ground demonstrations conducted in a timely manner. We will meet this need and provide this final step in the technology development by validating laboratory and ground tests through space, near-space, or ground demonstrations of new systems. By planning regular scheduled demonstrations, fast and efficient technology transition will be available to meet the user needs with confidence. By combining new technologies into mission oriented demonstrations, improvements in operations and tactics can also be demonstrated. The synergistic effect of operations, tactics, and new technologies will result in the maximum improvement in both life cycle costs and performance.

GOALS

The broad goals of the Advanced Space Technology Integration and Demonstration Thrust are to transition technology by:

- Providing integrated space flight demonstrations to address AFSPC identified deficiencies and weaknesses;
- Reducing cost of developing, launching, and operating space systems; and
- Minimizing risk associated with inserting advanced technology into the operational satellites developed by SMC and operated by AFSPC.

Methods to Meet Goals:

- Validate new satellite technologies using state-of-the-art and standard satellite configurations;
- Employ simplified command and control concepts;
- Involve the user in the planning and execution of advanced technology and integrated space flight demonstrations, including development of operational strategies based on advanced technology;
- Employ autonomous satellite operations;
- Perform enabling experiments and integrated demonstrations to transition advanced space system related technologies to users;
- Verify the maturity of technology;
- Emphasize a streamlined concept of operations with maximum use of experienced integrated product teams to include contractors, in-house expertise from all PL Directorates, the Air Force Laboratories, and other government agencies;
- Provide sustaining role in improving the laboratory's integration and system engineering capability;
- Provide actual experience in design, fabrication, integration, systems engineering and flight of spacecraft payloads to personnel; and
- Integrate and execute ground, near space and space demonstrations for other DoD agencies leveraging their technology developments to enhance AF capabilities.

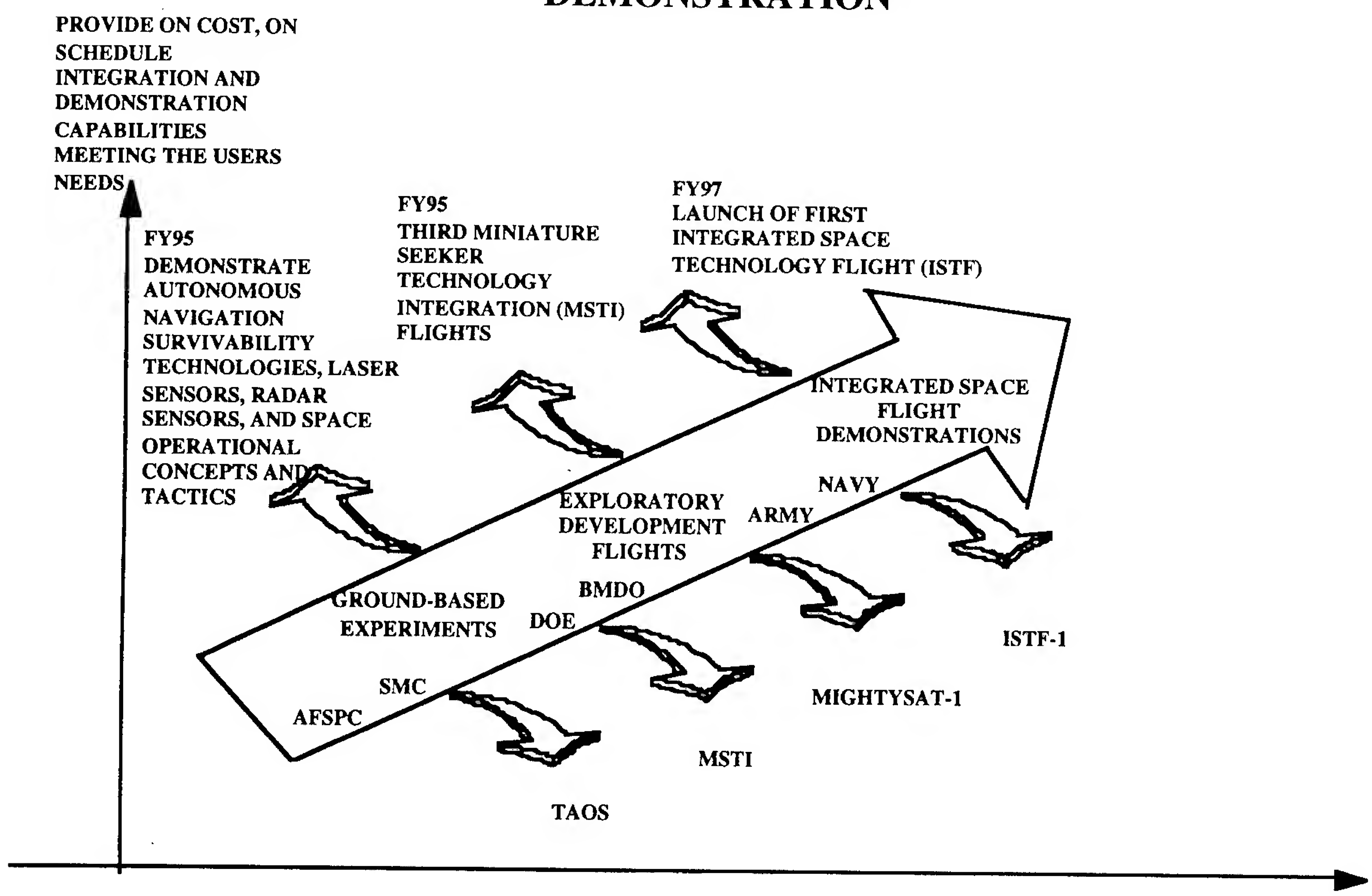
MAJOR ACCOMPLISHMENTS

Phillips Laboratory launched the Technology for Autonomous Operational Survivability (TAOS) integrated space flight demonstration in March 94 from Vandenberg AFB. For the past 12 months, experimenters from PL have worked successfully with Mission Control teams at Onizuka AFB and Cheyenne Mountain AFB to test the autonomous navigation survivability technologies as well as space tactics and concepts in an operational environment. To date, experiments and demonstrations involving the radar sensor and global positioning system receiver have been 100% completed, experiments demonstrating the autonomous navigation system have been 90% completed, the laser sensors have completed 80% of their experimentation while the operations demonstrations are only 50% complete. Additional demonstrations involving the payloads and operational concepts are to take place this summer. Anticipated shutdown of the TAOS mission and satellite is late Jul 95.

CHANGES FROM LAST YEAR

This Air Force technology thrust has historically received a disproportional amount of funding from external DoD customers (e.g. BMDO and ARPA). The continued decline in these funding sources along with drawdowns in Air Force funding has led to significant changes over the past year within the thrust. The declining budgets have led the Phillips Laboratory to put in place an institutional program to enable continued support to our users. A three-tiered program to provide a full-service, integrated set of complimentary demonstration capabilities ranging from ground-based

THRUST 4
ADVANCED SPACE TECHNOLOGY INTEGRATION AND DEMONSTRATION



"hardware-in-the-loop" experiments to technology flight experiments such as the MIGHTYSAT or balloon programs to integrated space flight demonstrations such as the Integrated Space Technology Flights (ISTF) program. The use of these three levels allows the Phillips Laboratory to validate emerging technologies in the most cost effective manner. Effective transition of technology from the laboratory to the operational commands will reduce the cost of future space systems while maintaining or increasing performance for the warfighter. Additionally, Phillips Laboratory has completed the construction of the new Aerospace Engineering Facility. This contractor-operated facility will provide the capability for hands-on integration and systems engineering for such programs involving MIGHTYSAT, balloons, and sounding rockets.

MILESTONES	YEAR	METRICS
TAOS Data Analyses Complete	FY96	Data Analyses Complete, Mission Shutdown, Distribution of Equipment
ISTF #1 Integration	FY96	Design, Fabrication, Integration Complete
ISTF #1 Launch	FY97	Launch Mission; Begin On-orbit Demonstration(s); Mission Objectives Met
ISTF #2 Initiation	FY98	Mission Defined
MIGHTYSAT #1 mission	FY97	Launch on Space Shuttle STS-81
MIGHTYSAT #2 mission	FY98	Launch on Space Shuttle or Multi-Service Launch System
Ground-Based Experiments Program Initiation	FY96	Experiments Integrated at Bench-Top Level; Data Analyses Begun
Miniature Sensor Technology Integration (MSTI) satellites	FY95	MSTI-3 Launch. All mission objectives met.

THRUST 5: SPACE POWER & THERMAL MANAGEMENT

USER NEEDS

Space Power and Thermal Management Plans and AFSPC Mission Area Plans. These include:

MISSILE WARNING - High efficiency power, long life cryocoolers, cooling for high density electronics
SPACE SURVEILLANCE - Low cost, high efficiency power, long life cryocoolers
NAVIGATION - Long life batteries/solar cells, light weight, low cost arrays, cooling for high density electronics
MILSATCOM - High efficiency power generation and distribution
RS&I - Light weight power system, advanced power management and distribution
SPACELIFT - Advanced photovoltaic power for upper stages, thermionic power for upper stages

GOALS

Our research and development strategy emphasizes identifying and developing <u>component</u> technologies that have dramatic impact on <u>total system</u> performance. Specifically, it is our space power goal to:

- Improve <u>total system</u> power performance from 4 W/kg to 15 W/kg by 2005 reducing costs from $10000/W to $5000/W.

We will pursue the following <u>component</u> level technology programs to meet this goal:

- High efficiency (30%) multi-junction solar cells and light weight thin film cells.
- Advanced flexible blanket and concentrator arrays with improved performance of 150 W/kg and .15m^2 stowed volume in the 1-3 kW range.
- Lithium ion and solid state battery technologies that are lower weight (50%), lower cost, less volume, and more reliable.
- Power management technologies (component and sub-system level) to reduce satellite mass while increasing modularity and satellite autonomy.

We also pursue high risk, high payoff technology programs, that if successful, promise revolutionary improvements in performance. These include:

- Non-electrochemical energy storage such as thermal energy storage, and non-photovoltaic energy conversion technologies.
- Thermionic conversion technology development necessary for a solar thermal bimodal power and propulsion system.
- Russian space component technology relevant to the US space power technology base.
- High (greater than 30% efficiency) energy conversion technologies for solar thermal power systems.

It is the goal of our thermal management technology programs to:

- Improve <u>total system</u> performance and lower life cycle costs by developing cryogenic mechanical coolers to replace cryogenic dewars, and
- Reduce <u>total thermal control system</u> weight by 20% by 2005.

Cryogenic cooler technology development enables advanced infrared sensors for space surveillance, satellite reconnaissance and new missile warning applications in the 2000 to 2005 timeframe. Our cryogenic cooler programs will:

- Develop 150 Kelvin (K) cryocoolers providing 1-3 W of cooling, 7 years of continuous life, and weighing less than 4.5 kg.
- Develop cryocoolers capable of operating in the 10-75K range with 10 year operational lifetimes.
- Develop and demonstrate cryogenic thermal control system integration technologies that keep induced vibration to less than 0.2 Newtons and reduce power consumption.

Spacecraft thermal control technologies dissipate or transfer heat away from critical components (integrated circuits, computers, etc.). We are pursuing the following technology programs:

- Capillary pump loops, heat pipes and other transport devices with 100-3200 W of heat transport capability and at least seven years of operational life.
- Carbon-carbon and other advanced materials for advanced and deployable radiators, and other applications.

MAJOR ACCOMPLISHMENTS

Established joint Navy, NASA and Air Force program to conduct life testing and failure analysis on Common Pressure Vessel (CPV) NiH2 batteries. Established failure mechanisms within the existing designs, supervised a contractor redesign and recommended new testing procedures for the batteries.

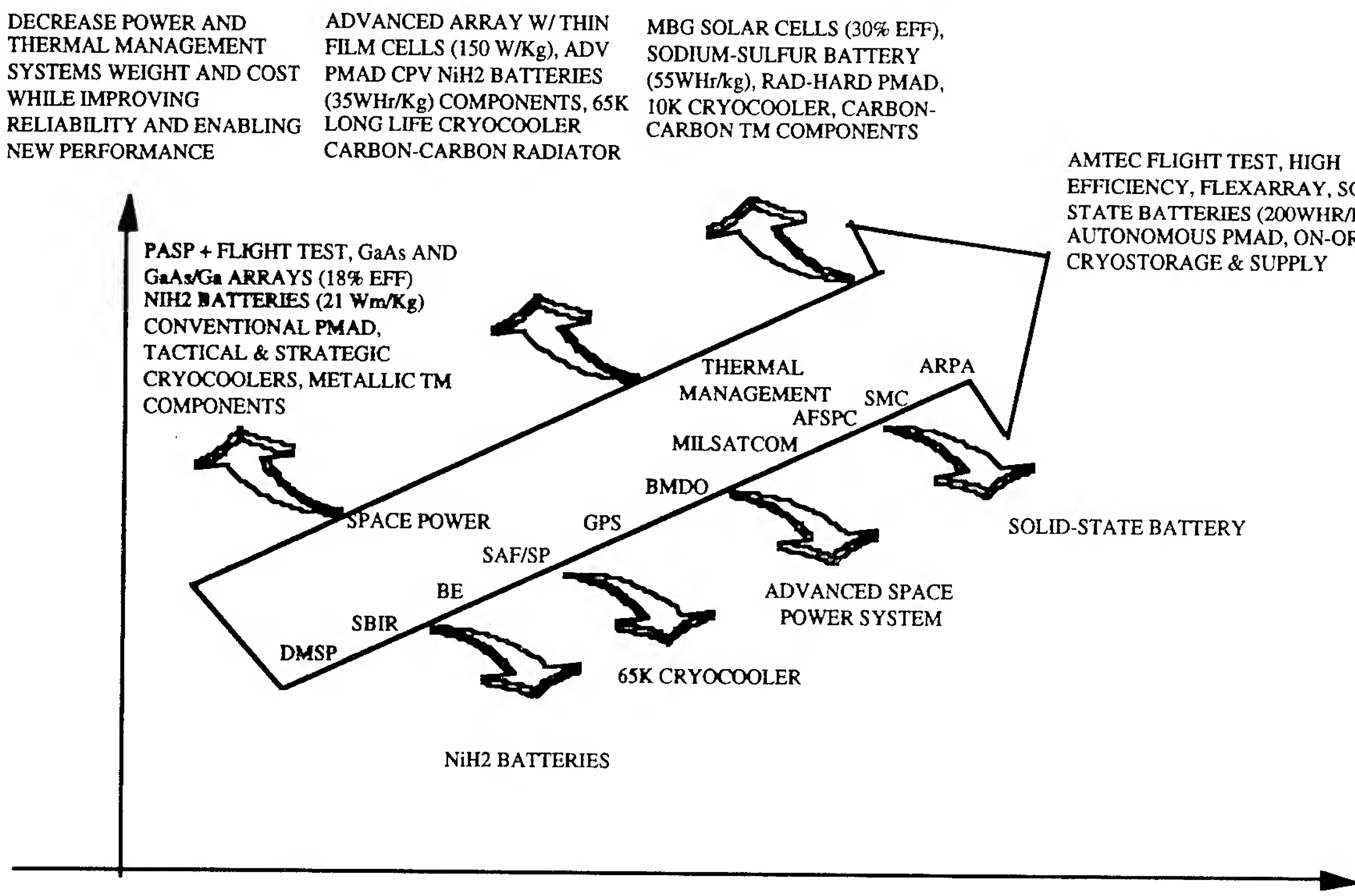
Completed design of the advanced Channel array, a flexible, composite substrate array with performance greater than 100W/kg and stowed volume less than .15m^3. Began ground testing of the array preparatory to launch on the NASA SSTI "Clark" in June 1996.

Completed manufacture and ground test of the BMDO fresnel lens concentrator array (90W/kg performance) and launched the array on the COMET satellite in July.

Accepted delivery of 25-27% efficient multijunction solar cells and completed laboratory characterization. Successfully led the effort for a joint PL, WL and NASA MANTECH program for the multi-junction cell starting in FY95.

Accepted delivery of forty 150WHr/Kg NaS cells and successfully completed ground and safety testing. Completed CDR for the NaSTEC flight experiment package scheduled for shuttle launch in FY 96.

THRUST 5
SPACE POWER AND THERMAL MANAGEMENT



Initiated a joint NRL, NASA and Phillips Laboratory program to design and possibly flight test a solar thermal bimodal power and propulsion system. We successfully completed preliminary design studies, component testing on the collection and thermionic conversion systems, and satellite specific system integration studies.

Demonstrated, for the first time, proof-of-principle design models of high reliability cryogenic cooler concepts (pulse tube and turbo Brayton) in support of user requirements at 35 and 65K.

Completed the design, fabrication, and initial operating capability of a capillary pump loop test bed which will enable the demonstration of lightweight, next generation, thermal control technologies.

Demonstrated high heat flux removal: (30 W/cm2) with advanced capillary pump, and (500 W/cm2) with microchannels.

CHANGES FROM LAST YEAR

The Space Nuclear Power Sub-thrust (5B) has been eliminated. Our only nuclear effort (TOPAZ) has been folded into the new Space Power Sub-thrust (5a).

MILESTONES	YEAR	METRICS
Transition multi-junction cell technology to MANTECH	FY95	Cell efficiency of 25%-30%
Conduct flight testing of multi-junction and thin-film cells on STRV-2	FY96	Transition emerging cells to SMC users
Qualify and flight test NaS battery	FY97	Tech transition 100 Whr/kg NaS batteries with 10 year lives
Flight test Channel and thin-film arrays	FY97	Demonstrate 150W/Kg, 0.15M3 arrays and transition to SMC
Flight test Solar Thermal Bimodal Power/Propulsion systems	FY98	Demonstrate OTV capability and launch vehicle stepdown
Develop and breadboard high voltage PMAD technology	FY 98	Demonstrate 100v, 90% efficiency PMAD components
Begin endurance characterization of 65 K cryocooler	FY 97	Demonstrate 2 watts of cooling
Capillary pump loop test bed operational	FY 96	Begin characterization of capillary pump loop components

THRUST 6: SPACE SENSORS & SATELLITE COMMUNICATIONS

USER NEEDS

Air Force Manual 1-1 states, "American military forces have come to rely on space-based systems for instantaneous worldwide communications, constant surveillance and early warning, accurate weather forecasting, and precise navigation." Specific users operational needs and the technology required to meet them are documented in AFSPC Mission Area Plans and SMC Development Plans. The Space Sensors and Satellite Communications Thrust develops many of the technologies identified in those plans. Improved booster detection sensitivity and coverage and worldwide detection and tracking capability for missiles and warheads in midcourse and terminal ballistic flight are needs identified in five mission area plans:

AIR FORCE SPACE COMMAND (AFSPC) MISSILE WARNING - improved IR focal plane arrays; active surveillance system

THEATER MISSILE DEFENSE - advanced infrared focal plane arrays

BMD/C3 - advanced mid- and long-wavelength focal plane arrays, multicolor focal plane arrays

RECONNAISSANCE SURVEILLANCE AND INTELLIGENCE - space based radar, high performance sensors

Many AFSPC and ACC Mission Area Plans and corresponding development plans identify the need for survivable, affordable C3 capability worldwide. Lightweight, high efficiency satellite communication is a key feature of the architecture needed to provide the need for such capabilities.

Ballistic Missile Defense needs for improved sensors for boost and midcourse targets are given in Joint Chiefs of Staff Memorandum, Joint Ballistic Missile Defense Operational Requirements, USCINCSPACE Operational Requirements for Phase I Strategic Ballistic Missile Defense, JROCM 064-91 and AF MNS 004-91.

GOALS

Passive Sensors' goal is to reduce development costs, weight, and power consumption; increase reliability, sensitivity, and resolution; and enhance affordability. This will be achieved by:

- Development of a new generation of improved, highly sensitive detectors to provide reliable missile warning by detection of dim targets, increased detection range, and improved clutter suppression.
- Development of multicolor detectors that will simplify sensor design resulting in significantly lower power requirements and lower weight.
- Develop low power infrared detector readout electronics to reduce sensor spacecraft power requirements by more than half and radiator weight by hundreds of pounds, improving the affordability and operability of space based missile warning and reconnaissance and surveillance satellites.

Active Sensors' goal is to identify, develop and transition key technologies for affordable, non-deniable, broad area, all-weather surveillance systems supporting Global Reach/Global Power. This will be achieved by:

- Developing Advanced Onboard Processing & Control technologies for data reduction, advanced signal processing, automatic target recognition, sensor fusion, and cross cueing, ensuring timely availability of reconnaissance and surveillance products to the tactical war fighter.
- Development of large, lightweight, multi-mode/band/ phenomenology antennas for space based military reconnaissance and surveillance missions and commercial dual-use applications.

Satellite Communications' goal is to identify, develop and transition affordable, high data rate technologies for our primary customer, MILSATCOM: This will be achieved by:

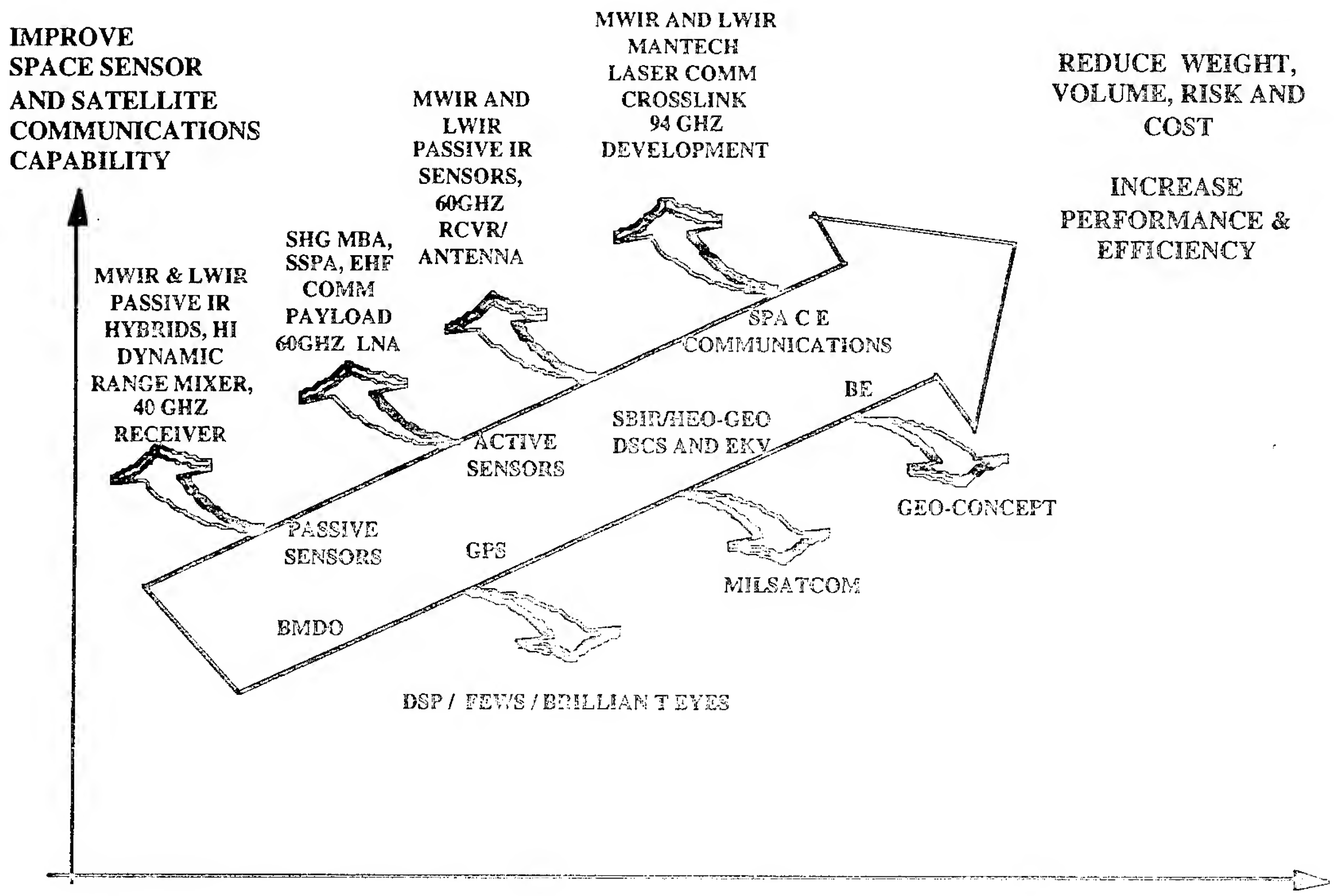
- Leveraging high efficiency, lightweight component and signal processing technology (DoD & commercial) to reduce the weight, volume and power requirements of space communication systems by more than half, making highly mobile and transportable services available to tactical forces feasible and helping provide affordable C3 capability for worldwide theater operations.

MAJOR ACCOMPLISHMENTS

FY95 marks the first year AF 6.2 and 6.3 funds were invested in this major thrust. Successfully transferred exploratory development work previously funded by BMDO in long-wavelength HgCdTe detectors and Quantum Well Infrared Photodetectors (QWIPs). Initiated work to identify and reduce performance limiting defects in HgCdTe. Development of a novel grating concept which could significantly enhance the performance of QWIPs. Initiated advanced development of very large mid-wavelength focal plane arrays.

Increasing support for Space Based Radar and the GEO concept. GEO concept is most promising approach for affordable, non-deniable, all-weather, broad area surveillance capability. Integrated PL sensor models into the Theater Air Command and Control Simulation Facility to provide a first generation capability for these types of simulations. This will be used to evaluate the operational utility of new space

THRUST 6
SPACE SENSORS AND SATELLITE COMMUNICATIONS



system architectures and concepts for fulfilling documented reconnaissance and surveillance needs, and ultimately support our technology trade studies and development efforts.

At the request of the MILSATCOM Program Office, we initiated efforts to mature technologies for MILSATCOM payloads and satellite buses. These efforts will drastically reduce the weight of future space communication systems, allowing launches on medium launch vehicles and saving tens of millions' dollars. Coordinated all of these efforts with ongoing 6.2 and 6.3 communication system development work at Rome Laboratory.

CHANGES FROM LAST YEAR

Will increase emphasis on QWIPs as HgCdTe detector technology matures. Will initiate development of multicolor detectors.

Congressional language restricted funding for advanced space communications work in PE 63401 Project 3784 in FY94, citing duplication of effort with MILSTAR technology development efforts. Adding evaluation and characterization of commercial components/technology for military applications.

We restructured the FY95 program to reflect coordination with system program offices and other AF laboratories

MILESTONES	YEAR	METRICS
Develop antenna for integration into 60GHz cross link	FY97	Antenna delivered and integrated
Develop and EHF test bed and integration facility	FY99	Integrate and test EHF systems
Transfer MWIR HgCdTe technology	FY96	Technology available for use in operational systems
Transition QWIPs technology to 6.3 arena	FY97	Initiate development of large QWIPs focal plane arrays
Demonstrate M&S capabilities and potential to customers	FY96	In-house connectivity of various models
Dedicated airborne testbed for Spaceborne surveillance tech	FY98	Demo sensor fusion capabilities with real-time info to users

THRUST 7: SPACE VEHICLE ELECTRONICS AND SOFTWARE

USER NEEDS

Electronics and software are as pervasive in space systems as they are in everyday life. AF SPOs, BMDO, and other space system developers have identified high performance, radiation hardened, space qualifiable, on-board signal and data processing subsystems as critical technologies for the late 1990s and beyond.

To meet these broad, user-defined needs, we must develop and demonstrate technologies that improve microelectronic components, operating systems, and algorithms. Often technology needs can be directly met by improving the performance, size, reliability, or cost of an electronic component, board, subsystem, or software tools.

Examples of the numerous technology needs identified in specific SMC TPIPT development plans are:

MISSILE WARNING - survivable high speed communications, decision support systems, high fidelity simulators and RF sensor model/sim tools

RECONNAISSANCE / SURVEILLANCE - rad-hard 32-bit processors, algorithms, high-speed on-board signal processing and fast target detection

SATELLITE CONTROL - Artificial intelligence and expert system ground decision aids, autonomous spacecraft and subsystem operations.

SPACELIFT - autonomous GN&C, advanced power conversion.

MISSILE DEFENSE - Multi-sensor fusion

GOALS

Our goal is to permit increased space system reliability, operability, autonomy, and affordability by providing development of next-generation electronics, software and M&S and demonstration of advanced components and methods. Specific goals are:

- Develop and demonstrate essential electronics (including 32-bit processors, memory, etc) for DoD with "spin-off" applications in NASA and commercial satellite programs
- Reduce Operation and Maintenance costs by as much as 50% by providing high speed, fault-tolerant electronics
- Reduce the number of expensive and vulnerable ground stations needed by at least 50% by increasing satellite autonomy
- Improve direct information transmission to field commanders by 100% through advanced electronics (e.g., signal processing systems) and algorithms.

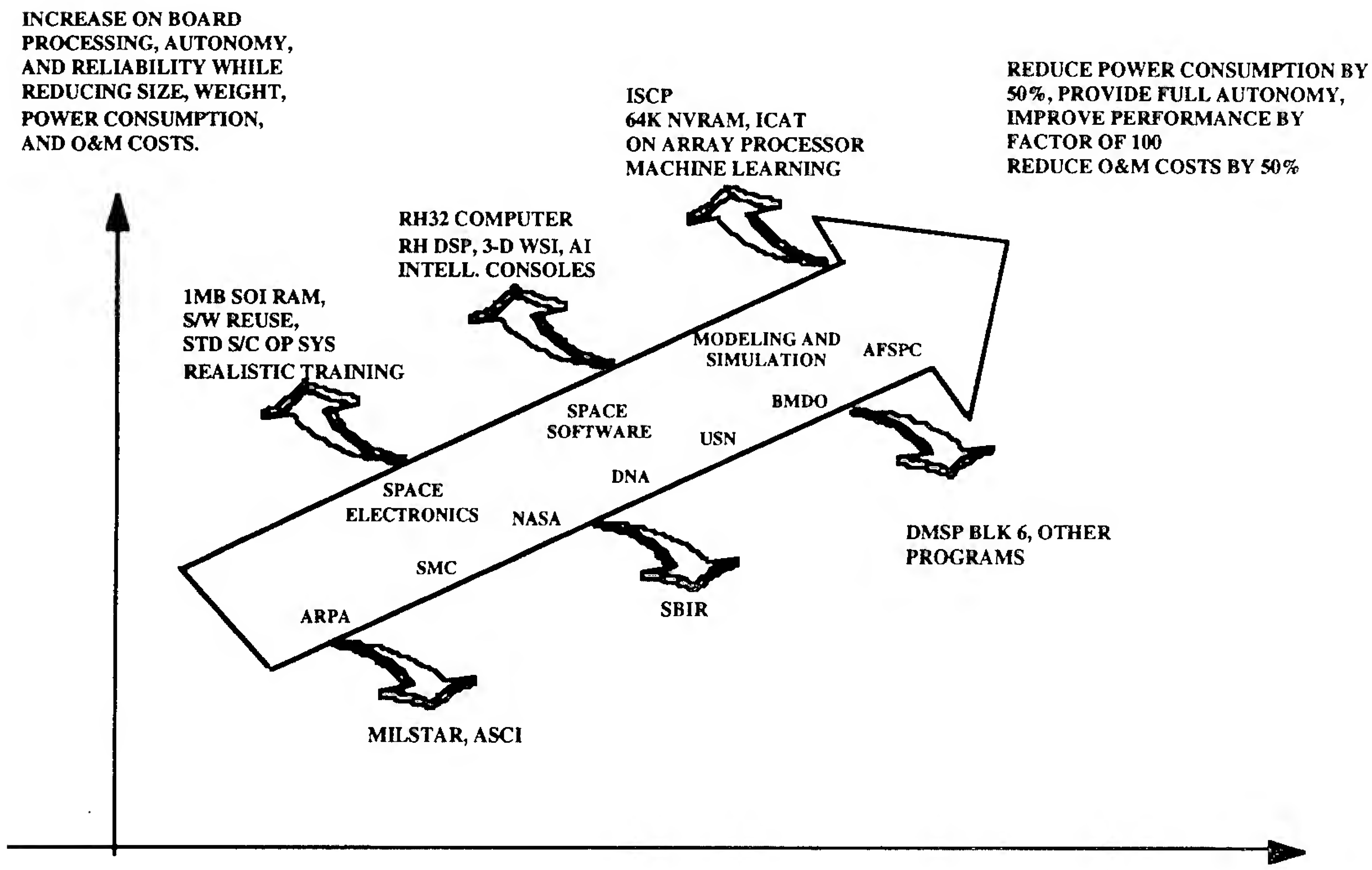
Key developments to meet the above goals are to:

- Provide at least a 10X improvement in AF space electronics systems capability in the next five years by:
  - Leveraging from the rapid progress being made in the commercial electronics industry
  - Developing the technologies to transition high-demand commercial integrated circuits to space qualifiable versions
  - Leveraging industry's huge commercial investment in design, software, and testability
  - Developing innovative hardening technologies and transferring them to industry
  - Building a standardized signal processing module
  - Demonstrating space qualifiable versions of commercial high speed data busses including the Fiber Distributed Data Interface and the Asynchronous Transfer Mode.
  - Improve interoperability by developing new computer architectures and standards which will reduce the customer's cost to develop and test systems by as much as 50%
- Develop space qualified versions of commercial integrated circuits and advanced packages which will:
  - Reduce the weight, volume, and power required by the next generation electronics, reducing battery, solar panel, and overall satellite structure weight thereby allowing use of smaller, less expensive launch vehicles
  - Increase the amount of electronics integration that can occur within a single package by 10X,
  - Improve system reliability by 100% by integrating more functions per electronics package, reducing the number of vulnerable wire interconnects
- Address deficiencies in satellite control by improving the producibility, affordability, and performance of space systems through space unique software research and development in:
  - Developing reusable, affordable software architectures, components, and tools for satellite systems including on-board and ground station processing to reduce acquisition and O&M costs by at least 50% while producing flexible systems that meet current and future needs.
  - Developing software concepts to achieve an optimum level of satellite autonomy and develop intelligent consoles for satellite control to improve orbit analysis and control capabilities. Reduce manpower required to control satellites by one third and address improvements in resource scheduling. Develop intelligent systems for ground stations to reduce operator workload and assist in anomaly resolution. Develop intelligent systems for satellites to reduce amount and complexity of data transmitted to the ground and improve safety of satellite operations.
  - Applying a disciplined engineering approach to the development and acquisition of software to improve the quality of space systems software and meet program cost and schedule requirements.
  - Build the Frontier Arena under AFSPC sponsorship to be an evolutionary, dynamic, distributed, interactive space M&S environment for technology development, and system development/acquisition.

MAJOR ACCOMPLISHMENTS

A Memorandum of Understanding was drafted with a consortium of SMC SPOs. The consortium will provide additional FY95 and 96 funding to complete the

THRUST 7
SPACE VEHICLE ELECTRONICS AND SOFTWARE



development of two 32-bit processor programs historically funded by PE63401F. The first single-event-upset tolerant RISC processor was fabricated. This processor provides a 10X increase in performance over 16-bit processors currently used in space and will be immune to upset from cosmic rays. Silicon-on-insulator gate arrays were designed to provide an important base technology for rapid prototyping of hardened Application Specific Integrated Circuits.

MILSATCOM project office agreed to fund three important technologies: design and demonstration of a miniaturized power converter, fabrication upgrade and improvement to a radiation hardened fabrication line, and design and prototype of a two-sided multichip module to provide a 2X improvement in memory densification.

We also completed the demonstration of single-layer multichip memory modules. Through a joint effort with ARPA and NASA, more than 100 modules will be space-qualified by NASA for a 1997 Tropical Rainfall Mapping space mission—the first ever demonstration of this technology in a mission satellite.

CHANGES FROM LAST YEAR

Initiated new programs to develop a space-qualifiable hardened commercial Digital Signal Processor and Field Programmable Gate Array (FPGA). Both products are essential to space systems as evidenced by more than 30 letters of endorsement we have received from potential users. The programs have and will continue to develop important techniques and tools for translating commercial electronics designs into space qualifiable products. These techniques will be applicable to other products, saving millions of dollars per product in design costs.

Frontier Arena is a new initiative to support AF customers and the warfighter with M&S needs.

Milestones	Year	Metrics
Complete development of space-qualified, commercial heritage digital signal processor single-board computer	FY96	Deliver Ada compatible signal processor running at 28 MFLOPS
Develop and fabricate space-qualifiable 8K field programmable gate arrays	FY97	Insert FPGA technology in 10 existing or future satellite systems
Develop ultra-thin high density interconnect technology for space	FY98	Demonstrate on space experiment and insert in one future space system
Develop Reusable Software Components for Satellites	FY95	Deliver to SMC
Demonstrate MAGIC Architecture in different satellite environments	FY96	Evaluate MAGIC Architecture

THRUST 8: SPACE VEHICLE AND MISSILE DYNAMICS TECHNOLOGY

USER NEEDS

World-wide range, rapid response, devastating power, no effective defense, constant readiness, secure CONUS basing, and low cost have been hallmarks of intercontinental ballistic missiles (ICBM) but the decreasing nuclear threat has led to cancellation of two major ICBM development and production programs. As a result, Minuteman III will stand as the lone, but powerful, U. S. ICBM force through 2020. The importance of maintaining this reduced nuclear force as a combat and cost effective weapon is recognized by AFSPC mission area plans and SMC development plan technology needs:

DETERRENCE - Thrust axial accelerometer, Range Instrumentation & flight safety, Next generation navigation instrument design, Missile guidance technology

Many of these technologies have additional applications as identified in other Mission Area Plans:

NAVIGATION: Gyroscopes, Accelerometers

ASTRODYNAMICS

The following user needs are addressed by Astrodynamics:

SPACE SURVEILLANCE: algorithms for space based sensors in SSN; improved scheduling and tasking algorithms for ground based sensors; improved search, detect and track algorithms for ground based sensors; improved element set initial formation, maintenance and propagation algorithms; and LADAR

NAVIGATION: improved orbit models

MISSILE DEFENSE: tracking and aim point algorithms; and high power laser.

GOALS

ADVANCED GUIDANCE TECHNOLOGIES

- Develop GPS accuracy enhancements for range instrumentation & safety instrumentation
  - Flight the Missile Technology Demonstration at White Sands Missile Range in cooperation with U. S. Army, Navy, and the Defense Nuclear Agency
  - Demonstrate real time, GPS aided navigation solutions at ballistic missile velocities
  - Match the navigation data to range radar data to check for accuracy
- Miniaturize range instrumentation & safety packages
- Develop anti-jam antennas
- Alternate Guidance Replacement
  - Reduction of life cycle costs
  - Dormant operations
  - Maximize commercial technology
  - Affordable guidance units
- Integrate plasma physics with design
- Develop and test materials for antenna windows

ASTRODYNAMICS

- Improve differential correction (DC) accuracy by 90%
- Improve propagation accuracy at the end of the prediction period by 90%
- Demonstrate integrated performance of high accuracy lasers and astrodynamics algorithms to precisely locate and illuminate spacecraft
- Demonstrate next generation initial orbit determination, DC and propagation for space surveillance
- Show deficiencies in current operational DC and propagation which could be eliminated
- Demonstrate capability to maintain independent high accuracy catalog of selected satellites (20-30 objects)

MAJOR ACCOMPLISHMENTS

Successful flight of the Missile Technology Demonstration. This flight showed on board real time navigation solutions for range instrumentation and safety.

Plasma testing of antenna window materials. This is a joint project with Wright Laboratory Materials Directorate.

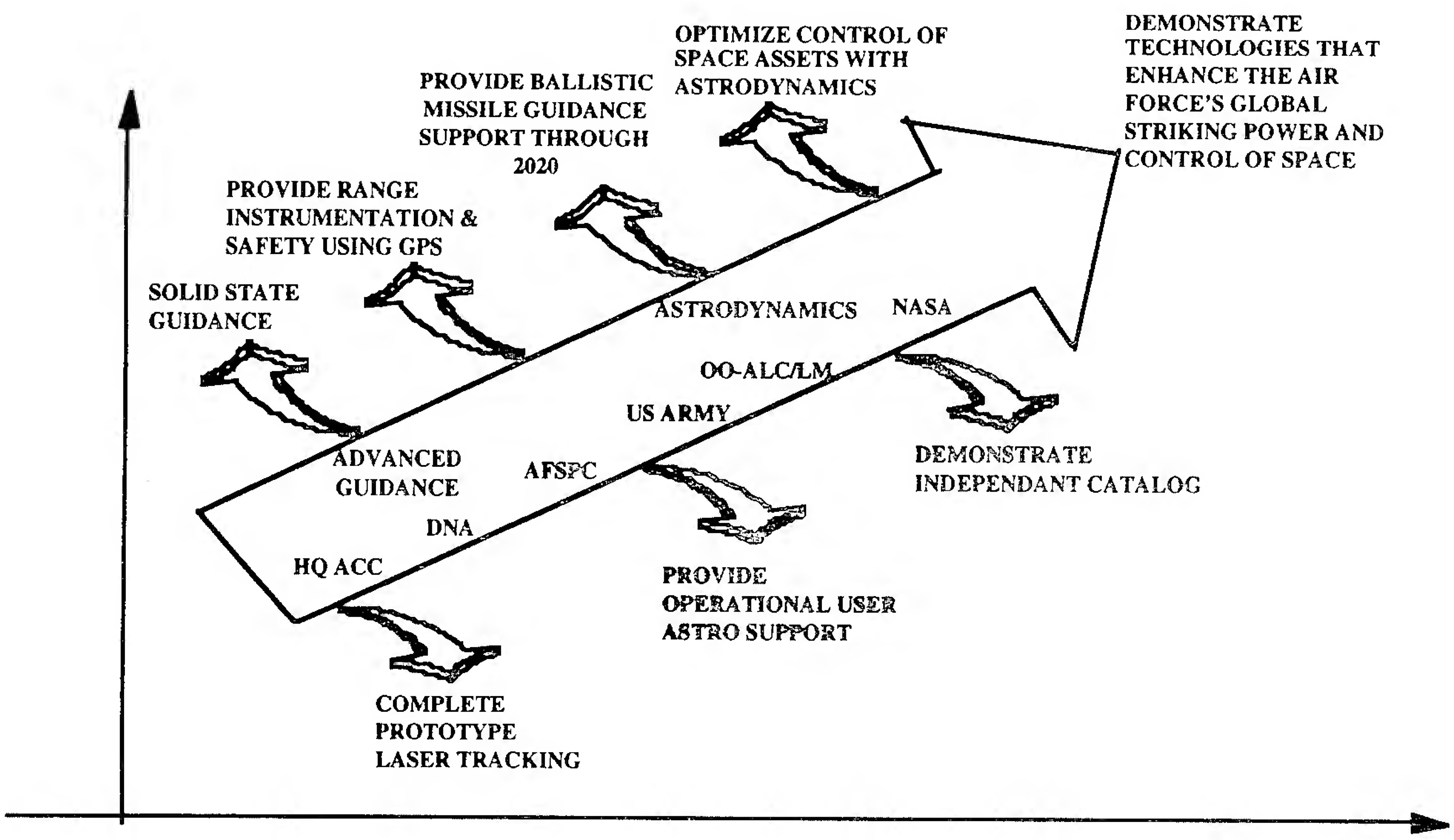
ASTRODYNAMICS

The following accomplishments were completed: 1) PC based orbit determination, identified deficiencies in AFSPC orbit software for processing highly elliptical orbits 3) HI-CLASS laser demonstration, 4) operational support for USSPACECOM , AFSPC and PL, 5) benchmark of operational orbit software for the Space Warning System Center, 6) evaluation of commercially available orbit software.

The second draft of an astrodynamics textbook is in progress. The initial draft was field tested in graduate classes at the Naval Postgraduate School. This textbook documents astrodynamic routines and computer code. Use of this new reference text to train engineers and satellite operators will help standardize algorithms and prevent the need for stovepiping astrodynamics specialists within organizations

A major research program for astrodynamic parallel processing for propagation and differential correction is continuing.

THRUST 8
SPACE VEHICLE AND MISSLILE DYNAMICS TECHNOLOGY



CHANGES FROM LAST YEAR

Congressional language required Advanced Guidance and Reentry Vehicles be extensively modified. Advanced Guidance funds were reduced by more than $15M. This amount of money allowed us to complete the Critical Design Review.

Responding to Congressional language, the Reentry Vehicle effort was terminated in FY95. Reentry materials are being pursued by the Materials Directorate.

MILESTONES	YEAR	METRICS
Solid State Guidance Instrument Technology	FY97	Guidance instruments one-tenth current size
Adaptive antenna technology	FY98	Demonstrate GPS antijam antenna in ground tests
Antenna window technology test	FY96	Reduce ablation 25% in load carrying windows
Complete demonstration of high accuracy laser tracking	FY96	Locate and illuminate representative satellites from all orbit classes
Implement new propagator in SSC	FY97	Reduce sensor taskings by 25%
Implement independent integrated surveillance system	FY98	Develop algorithms for upgraded SSC which increase performance by 30%
Implement algorithm for debris analysis	FY96	Develop analytic capability to model debris for periods of up to 6 Months
Mission planning support & ops guidance	FY97	Create algorithm for optimal orbit raising and repositioning
New model orbital resonance algorithm	FY96	Enable SSN to track deep space resonant orbits
Provide model of nonmaintainable orbits	FY97	Develop capability to accurately model and track nonmaintainable orbits within 20 km

GLOSSARY

A

ACC	Air Combat Command
ACTEX	Active Controls Technology Experiments
AFMC	Air Force Material Command
AFOSR	Air Force Office of Scientific Research
AFSPC	Air Force Space Command
AIMS	Advanced Inertial Measurement System
ARIES	Applied Research In Energy Storage
ARPA	Advanced Research Projects Agency
ASC	Advanced Structural Components
ASIC	Application Specific Integrated Circuits

B

BMDO	Ballistic Missile Defense Organization

C

CONUS	Continental United States
CPV	Common Pressure Vessel

D

DC	Differential Correction
DRA	Defense Research Agence
DSP	Defense Support Program

E

ESA	European Space Agency

G

GEO	Geosynchronous Earth Orbit

H

HEDM	High Energy Density Matter

I

ICBM	Intercontinental Ballistic Missile
IHPRPT	Integrated High Payoff Rocket Propulsion Technology
ILIP	Inter Laboratory Investment Plan
ISTF	Integrated Space Technology Flights

J

JDL	Joint Director of Laboratories
JPL	Jet Propulsion Lab
JSPP	Joint Service Program Reconnaisance

M

M&S	Modeling and Simulation
MAGIC	Multimission Advanced Ground Intelligent Control
MAJCOM	Major Command
MANTECH	Manufacturing Technology
MAP	Mission Area Plans
MILSATCOM	Military Saltellite Communication

N

NaSTEC	Sodium Sulfur Technology
NRL	Naval Research Laboratory

O

O&M	Operations and Maintenance

P

PASP+	Photovoltaic Array and Space Power plus
PL	Phillips Laboratory
PMAD	Power Management and Distribution

Q

QWIP	Quantum Well Ingrared Photodetectors

R

RL	Rome Laboratory

S

S&T	Science and Technology
SCVP	Structural Control and Vibration Damping
SEU	Single Event Upset
SMC	Space & Missile Systems Center
SOI	Silicon on Insulator
SPO	System Program Office
SSTI	
STIG	Space Technology Integagency Group
STRV	Space Test Research Vehicle

T

TAOS	Technology for Autonomous Satellite Operations
TAP	Technology Area Plan
TPIPT	Technical Planning Integrated Product Teams

U

USSPACECOM	United States Space Command

W

WL	Wright Laboratory